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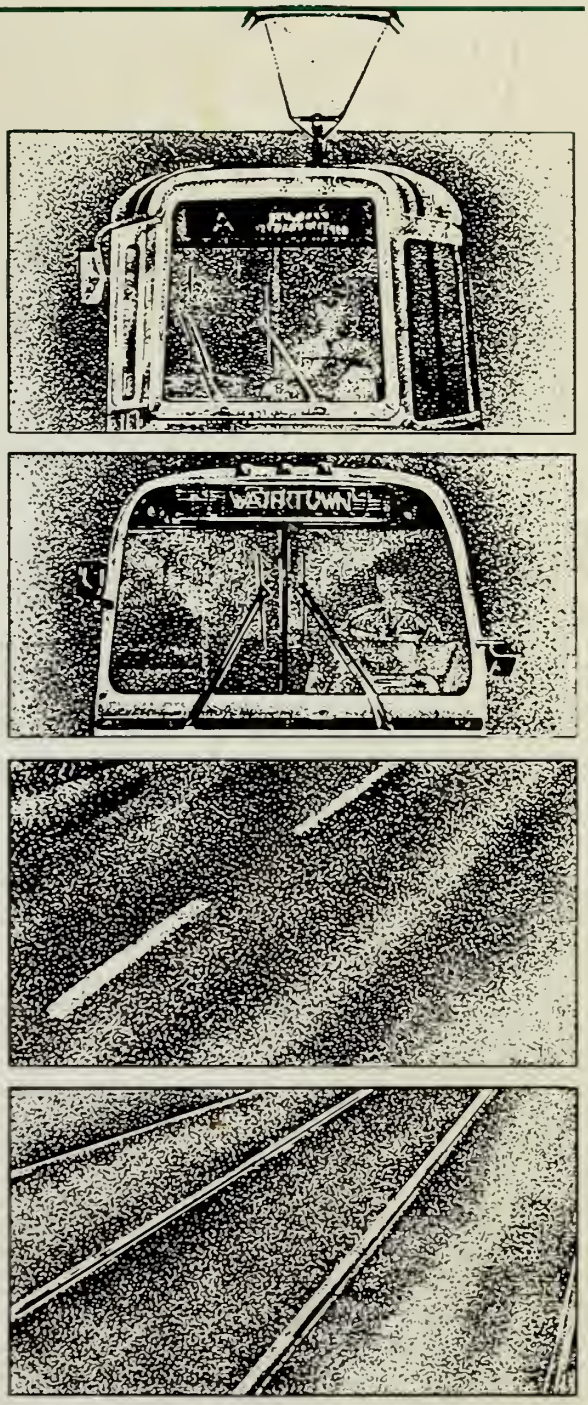

watertown TROLLEY ANALYSIS

appendices

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appendices

Authors
Karl H. Quackenbush - Project Manager
Erik Holst-Roness
Thomas J. Humphrey
Geoff Slater

Graphics
Mary Kean

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APPENDIX A RIDERSHIP PROJECTIONS

A.1 GENERAL APPROACH

At present, the areas that would be served by the A-line are served by Routes 57 and 301. With the re-introduction of trolley service, most increases in ridership would occur to the extent that light rail service would be more attractive than current bus services. This could take place in three major ways. First, for most riders, fares would be lower with light rail service than with current services. Second, for trips with one end east of Kenmore Station, a transfer would be eliminated. The elimination of the transfer in itself would eliminate a significant deterrent to ridership, while also decreasing waiting times and overall travel times. Third, if reservations, tunnels or signal pre-emption were utilized, LRVs could operate at a higher speed than buses operating in mixed traffic, further shortening travel times. However, at the same time, LRVs, with their higher passenger capacities (upwards of 130 compared to approximately 65 for buses), can carry more passengers with fewer trips. In many cases, this may result in longer headways than for bus service, therefore increasing wait times and offsetting some or all of the time savings that otherwise may occur.

The ridership projections contained herein account for each of the four factors discussed above by applying various elasticities to the changes in service attributes that would occur with the re-introduction of trolley service. Four types of elasticites were used: wait time, travel time, fare and headway. This process resulted in estimates of A-line surface ridership,[1] the increase in subway ridership that would result from A-line service in the subway, substitute bus ridership, and transfers from the substitute bus to the A-line.

During the course of the study, a large number of light rail (trolley) alternatives were examined. Including all five alternative outer terminal locations, the two inner terminal locations, and the various options for substitute

[1]For these purposes, surface ridership is considered to be any trip involving travel completely or partly on the surface portion of the A Line alternative being considered. Subway ridership is considered ridership completely within the subway.

bus service and reducing travel time, upwards of 30 alternatives were considered at various levels of detail. Detailed ridership projections were made for the six trolley and two bus alternatives presented in the body of the report, with more generalized estimates prepared on the other options. These other options are similar to those for which detailed projections were made, but involve an inner terminal located at Government Center instead of Park Street, the use of signal pre-emption, trolley reservations, and/or a tunnel in the Brighton Center area.

A.2 BASIC METHOD

In summary, this analysis takes the approach that two distinct markets are now being served by existing Routes 57 and 301. Were A-line service to be re-instituted in place of or in addition to these existing services, its major base of ridership would come from these markets. In addition, by adding more service along Commonwealth Avenue between Packard's Corner and Kenmore Square, and in the central subway, some of the B Line and central subway markets would also be served. The method used in this analysis focuses on demand from the Route 57 and 301 markets, and also includes additional ridership that would be generated in the central subway.

However, neither additional ridership along the common segment of the A and B Lines on Commonwealth Avenue, nor possible diversion of riders from the B Line to the A-line were assumed. Additional ridership along Commonwealth Avenue was not assumed based upon actual experience on the B Line: since March 1985, when headways were lengthened, there has been no apparent change in ridership. As a result, if headways were shortened by the addition of A-line service along that segment, presumably there would again be no significant change in ridership. Diversion from the B Line was not included in order to not place trolley alternatives at a disadvantage with bus alternatives (if ridership from the B Line were included, ridership, operating costs, and capital costs would be higher, but revenues would remain constant).

Within this general framework, an initial assumption was then made that the Watertown Square to Park Street A-line alignment (Alternative 2) would serve essentially the same market as existing Routes 57 and 301, with additional adjustments made for other alternatives. This process was performed through a number of consecutive steps as described below. An example of the calculations for Alternative 4a is also included in Attachment A1.

1. *Estimate of Percentage of Route 57 and Route 301 Ridership that would be Served by the A-line Alternative.* Based upon the location of the inner and outer terminals, an estimate was made of the percentage of the existing Route 57 and 301 riders that would be served by the A-line alternative. For outer terminal locations, adjustments were based upon load profiles of Route 57 and 301 ridership developed from ridecheck data collected for the Central North Bus Study (in the Fall of 1984) and the West Corridor Bus Study (in the Spring of 1986). Based upon these load profiles, a determination was made of how many existing Route 57 and 301 riders would be within 1/2 mile walking distance of the end of the new service. For each alternative, if Route 301 were to be eliminated, these figures would be as shown in Table A-1.

Table A-1
Percent of Route 57 and 301 Markets
Served by Study Alternatives
(assuming elimination of Route 301)

	Route 57	Route 301
Bus Alignments		
0. Base Case	100%	100%
1. w/ Free Transfer	100%	100%
Trolley Alignments		
2. Watertown Sq - Park St	100%	100%
3. Newton Corner - Park St	89%	100%
4. Oak Sq - Park St	69%	84%
5. Brighton Ctr - Park St	51%	20%
6. Union Sq - Park St	27%	0%

In alternatives where Route 301 would be retained, it was assumed that all Route 301 riders would continue to ride Route 301 rather than switch to the Green Line. This was assumed since, for the most part, peak-period riders are more concerned with reliability, seat availability and a one-seat ride than with fares. As a result, in these alternatives (4b, 5 and 6), it was assumed that the A-line would serve zero percent of the Route 301 market.

2. *Estimate of Impact on Existing Ridership Due to the Fare Difference on the A-line and the Elimination of the Transfer at Kenmore.* Most riders would be charged a lower fare on the A-line than on existing services, due to the lower fare charged on surface Green Line service and/or the elimination of the transfer charge at

Kenmore. Average one-way fares (based upon the fare mixes of Route 57 and 301 riders) for all of the fare combinations applicable to this analysis are as follows:

Table A-2
Average Fares for Study Alternatives
(average of inbound and outbound fares)

Bus Alternatives	
Route 57 only	$0.38
Route 301 only	$0.78
Route 57 & Green Line	$0.84
Rt 57 & Green w/free transfer	$0.42
Trolley Alternatives	
Substitute Bus only	$0.38
Substitute Bus & Green Line	$0.87
Surface A-line only	$0.35

With continuation of existing bus services, a free transfer at Kenmore would be the equivalent of a 50 percent fare reduction for riders transfering between Route 57 and the Green Line. As a result, for trolley alternatives, all ex-Route 57 riders directly served by the A-line, including both transfer and non-transfer riders, would experience an average of a 23 percent fare decrease. Ex-Route 301 riders directly served would receive an average of a 37 percent fare decrease. Using a fare elasticity of -0.35,[2] a free transfer at Kenmore for Route 57 riders would be expected to result in a 17.5 percent increase in transfers between Route 57 and the Green Line. For the trolley alternatives, the fare decreases would be expected to result in approximately an eight percent increase in trips from the Route 57 market, and a 13 percent increase from the Route 301 market.

In addition to the lower fare that would result from the elimination of a transfer at Kenmore, a significant time savings would result as well. At present, and

[2]All elasticities used in this analysis are based upon information presented in Patronage Impacts of Changes in Transit Fares and Services, Mayworm et. al., U.S. Department of Transportation, September 1980.

including a 5 minute transfer penalty,[3] an average trip involving both Route 57 and the Green Line involves the equivalent of 11 to 16 minutes of wait time (depending upon the time of day). With the elimination of the transfer, and if the new A-line service operated at the same headways as other Green Line service at Kenmore,[4] this could be theoretically reduced to 3 to 7 minutes. Using an elasticity for wait time of -0.30, these time savings would result in increases from the Route 57 market of 17 to 22 percent.

3. *Estimate of Ridership on the Substitute Local Bus Service (if provided).* With the elimination of Route 57, existing riders would be either served by the new A-line or substitute bus service, or be left unserved. If substitute local bus service is provided, ridership on the substitute bus would be the number of ex-Route 57 and 301 riders not directly served by the A-line (or Route 301, if retained), adjusted to account for assumed substitute bus headways, the number of forced transfers to the A-line, and the additional fare incurred because of the transfer.

   For riders that would not transfer to the A-line, the impact of the assumed bus headways was addressed by applying the headway elasticities shown in Table A-3 to the resulting percent change in headways. Depending upon the alternative, substitute bus service would operate at headways of 33 percent shorter (6 minutes versus 8 minutes) to 233 percent longer (20 minutes versus 6 minutes) than current Route 57 or 301 services. This would result in ridership changes on the substitute bus service, by time period, of a 9 percent increase to a 63 percent decrease.

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[3]The transfer penalty is applied in addition to the actual transfer time, and assumes that making the transfer is equivalent to the inconvenience of waiting an additional five minutes.

[4]This assumption is made only to achieve an intermediate calculation. In actuality, A Line service would operate at significantly longer headways than do other Green Line services at Kenmore (the combined headways of the B, C and D Lines). Adjustments to account for this are made beginning in Step 6.

Table A-3
Headway Elasticities

Original Service Level	Peak	Off-Peak
<10 Minute Headways	-0.27	-0.19
10 - 50 Minute Headways	-0.32	-0.49

For riders transfering to the A-line, the impact of additional wait time resulting from longer substitute bus headways and the transfer was treated in a similar manner as were transfers between Route 57 and the Green Line at Kenmore. However, in this case, a transfer is imposed, rather than eliminated. The same 5 minute transfer penalty was used[5], and an elasticity of -0.30 applied to the difference in total wait time. The total number of Route 57 and 301 riders who would potentially make the transfer was determined from the load profiles cited previously. In most cases, due to the much longer A-line headways at the outer terminal (compared with those at Kenmore), relocation of the transfer point would be expected to result in a large shift in ridership to other modes. In theory, wait times in some cases could be increased to the point where all existing riders would shift to other modes. However, in practice, no matter how inconvenient the transfer, some transit-dependent riders would have no choice but to utilize the new service. Therefore, based upon the relative levels of transit dependency in the Route 57 and 301 markets, ridership losses caused by the imposition of a transfer were constrained to a maximum of 63 percent for Route 57 and 84 percent for Route 301.[6]

Further, the imposition of a transfer at an intermediate point along the alignment of Route 57 would result in a fare increase for most patrons. Trips entirely on the surface travelling through the transfer point would then require payment of both local bus and surface trolley fares. In addition, for trips to downtown Boston, the inbound transfer to the A-line

[5]As in Step 2, the transfer penalty is added to the actual transfer time.

[6]Based upon Central North Bus Study and West Bus Study survey data, 74 percent of Route 57 riders and 32 percent of Route 301 riders did not have an auto available for their trip. Of these riders, it was assumed that 50 percent would have no other option than to ride the substitute bus and the A Line regardless of the additional time required.

would occur on the surface, where the trolley fare would be 75 cents, rather than at Kenmore, where the fare would be 60 cents. The combination of these factors would result in an average of a 20 percent fare increase for ex-Route 57 riders, and an 11 percent fare increase for ex-Route 301 riders. Using an elasticity of -0.35, the net impact would be an additional 4 to 7 percent ridership decrease in addition to losses due to imposition of the transfer itself (within the ridership loss constraints imposed above).

4. *Estimate Total Ridership on the A-line Assuming A-line Headways are the Same as on Existing Bus Services.* This figure would be the sum of Step 1, Step 2 and the number of transfers from the substitute bus service to the A-line from Step 3.

5. *Determine Trolley Headways Required to Serve Demand Calculated in Step 4.* In this step, the capacity of light rail vehicles is matched to the demand calculated in the previous steps. During all periods, one car trains are assumed with service designed to carry an average peak load of 130 passengers (compared to a bus capacity of approximately 60 to 65 passengers), but with headways of no longer than 15 minutes during any time period. (Based on a combined Route 57 and 301 load profile, the maximum load point on the surface would occur in the vicinity of Boston University with 85 percent of total riders per trip on-board.)

   Although a headway of 15 minutes may often be adequate to meet demand, it is sometimes more efficient to provide a slightly shorter headway in order to achieve a lower cycle time, while still maintaining adequate recovery time. In this manner, vehicles are utilized in revenue service to the greatest extent possible, with layover times minimized, thus resulting in shorter headways and higher ridership. This was done wherever possible.

6. *Based Upon Headways Calculated in Step 5, Adjust Ridership Estimates to Reflect Actual Headways*
   Ridership estimates to this point have been made under the assumption that A-line headways would be the same as existing bus headways. In this step, ridership is adjusted based upon revised headways by applying elasticities to the percent difference between trolley headways and Route 57 and 301 headways. The same headway elasticities presented in Step 3 (Table A-3) were also applied in this step. Depending upon the time of day, the alternative and the market, ridership

changes caused by headway differences could range from a maximum increase of 12 percent (Route 301 market - school peak), to a maximum decrease of 41 percent (Route 57 market - AM peak).

7. *Recalculate Steps 5 and 6 based on revised ridership figures from Step 6 until headways match demand.* If significant changes in demand occured as a result of Steps 5 and 6, it was necessary to re-estimate the level of service that would be needed to supply demand. To do so, up to five iterations of Steps 5 and 6 were performed until demand estimates stabilized (again, with a maximum headway of 15 minutes).

8. *Estimate Increase in Central Subway Ridership due to Addition of A-line Service.* With the re-introduction of the A-line, service in the subway portion of the Green Line between Kenmore and Park Street or Government Center would also be increased. The impact of this additional service would be to reduce headways slightly, and also to alleviate crowding somewhat.

   To estimate the additional ridership that would result, projections were based on the reduced wait time that would result in the subway. On this basis, average headways in the subway with and without A-line service would be as follows:

Table A-4
Central Subway Headways
(Copley - Park Street)

	Early AM	AM Peak	Mid-day	School Peak	PM Peak	Evening /Night
Existing	1.4	1.4	1.2	1.2	1.6	2.0
w/A-line	1.2	1.2	1.2	1.0	1.4	1.8

   Based upon wait times at 50 percent of these headways, the wait time elasticity of -0.30 was applied to the percentage decrease in wait time. On an overall basis, the slightly reduced headways and lower level of crowding could result in an increase in subway ridership of about two percent.

9. *Estimate Total Ridership Attributable to Alternative* The total ridership attributable to each alternative would be the total of A-line surface ridership, the

increase in subway ridership, substitute bus ridership, and Route 301 ridership.

Through use of this process, ridership estimates were developed for all components of each alternative by time period. Also, based upon the iterative process that matched headways to demand, trolley vehicle requirements were determined. These estimates, as well as a complete listing of all assumptions used for each alternative, are included in Attachment A2.

A.3 SUMMARY OF RIDERSHIP ESTIMATES

As shown below, combined ridership on all components of each alternative is projected to range from a low of 11,360 trips per weekday (Alternative 6) to a high of 14,370 trips per weekday (Alternative 2) (see also Figure A-1).

Table A-5
Summary of Demand Estimates
(weekdays - total unlinked[7] trips; both directions)

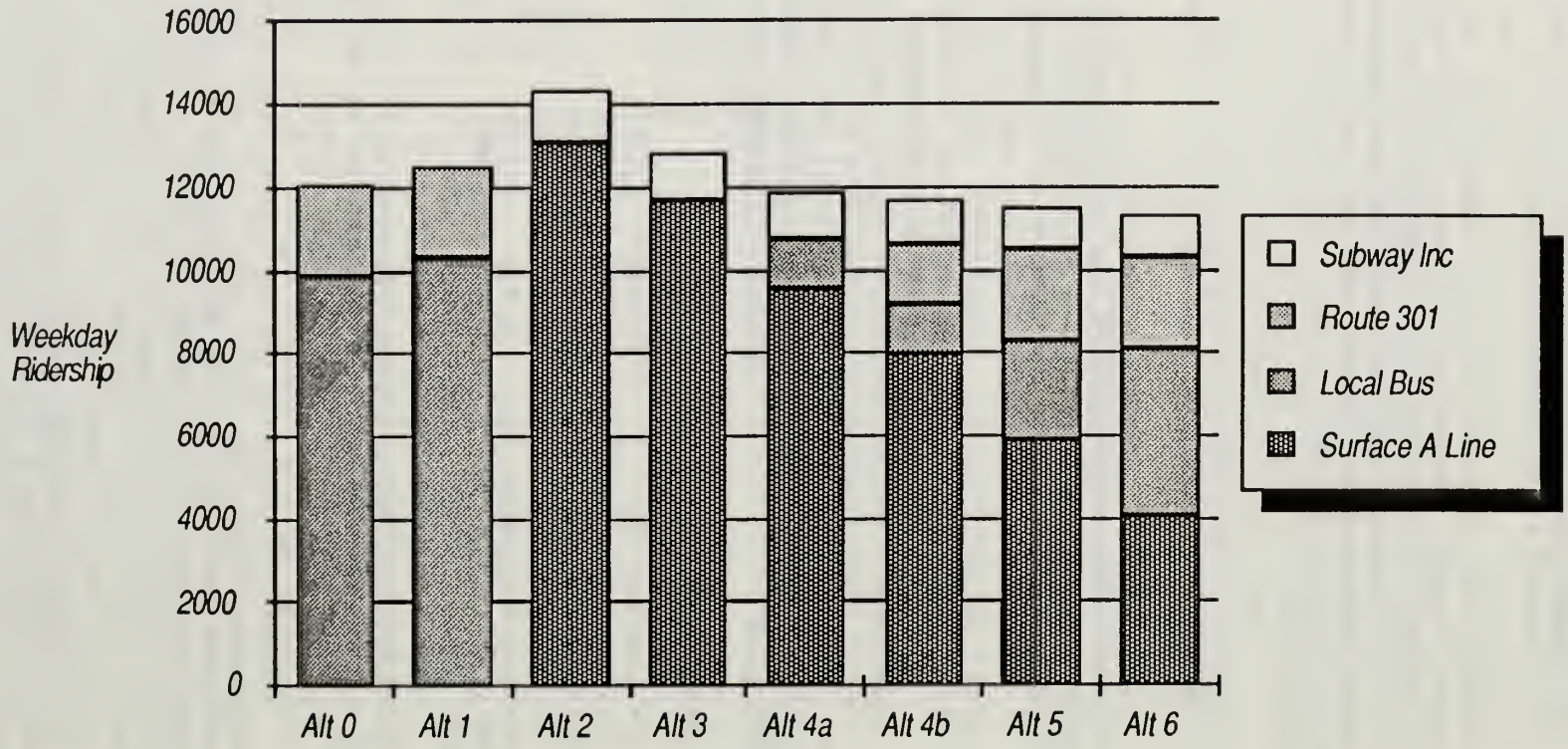
Alternative	Surface A-line	Subway Increase	Local Bus	Route 301	Total
0. Base Case	0	0	9,870	2,220	**12,090**
1. w/Free Transfer	0	0	10,340	2,220	**12,560**
2. A-line-Wat Sq	13,120	1,250	0	0	**14,370**
3. A-line-Newt Cr	11,700	1,180	0	0	**12,880**
4a. A-line-Oak Sq	9,570	1,120	1,220	0	**11,910**
4b. A-line-Oak Sq	8,020	1,040	1,170	1,490	**11,720**
5. A-line-Brighton Ctr	5,910	1,020	2,400	2,220	**11,550**
6. A-line-Union Sq	4,070	1,040	4,030	2,220	**11,360**

Although the total range between alternatives is not large, ridership losses with Alternatives 4a through 6, in terms of the number of individuals served, would be greater than indicated by the figures above. Many of the local bus

[7]An unlinked trip refers to any trip made on a specific service, and does not consider whether other transit services or other modes are also used as part the same one-way trip. A linked trip "links" together all unlinked trips made as part of the total one-way trip. Unlinked trip figures are used to determine useage of a specific service and the amount of revenue that would be generated, while linked figures provide a better indication of the number of individuals that would be served.

Figure A-1

WATERTOWN TROLLEY ANALYSIS
Weekday Ridership, by Alternative



and A-line trips in these alternatives would be made by the same individuals as part of the same one-way trip. In these alternatives, although fewer individuals would be served, many of the remaining riders that previously used only Route 57 would instead have to ride both the substitute bus and the A-line, both of which would count as a separate unlinked trip. As a result, the total number of unlinked trips made on the combined services would not decrease to the extent that the number of individuals served, or linked trips, would decline.

With the combination of services considered in this analysis, the total number of linked trips can be determined by substracting the number of transfers between the substitute bus service and the A-line from the total unlinked trip figures. In addition, assuming that the average A-line rider would make 2.1 one-way trips per day[8], the average number of individuals served by each alternative was also estimated, as shown below.

Table A-6
Total Number of Linked Trips and Individuals Served
(Average Weekday)

Alternative	Total Unlinked Trips	Sub Bus/ A-line Transfers	**Total Linked Trips**	**Number of Individuals Served**
0. Base Case	12,090	0	**12,090**	**5,760**
1. w/Free Transfer	14,560	0	**12,560**	**5,980**
2. A-line-Wat Sq	14,380	0	**14,380**	**6,850**
3. A-line-Newt Cr	12,880	0	**12,880**	**6,130**
4a. A-line-Oak Sq	11,910	1,080	**10,830**	**5,160**
4b. A-line-Oak Sq	11,720	1,020	**10,700**	**5,090**
5. A-line-Brighton Ctr	11,550	1,450	**10,100**	**4,810**
6. A-line-Union Sq	11,360	1,910	**9,450**	**4,500**

Irrespective of the ridership measure used, ridership was most sensitive to the imposition or elimination of transfers and the resulting fare change, followed by trolley headway changes. A-line ridership was highest in alternatives where transfers or transfer charges were eliminated (Alternatives 1, 2 and 3), and lowest in alternatives where new transfers were imposed (Alternatives 4a, 4b, 5 and 6). Significant ridership data for each alternative is as follows (all ridership figures refer to unlinked trips):

[8]Based on ridership habits of pass users system-wide.

- *Alternative 0 (Base Case) - Existing Route 57 and 301 Services* Based upon Central North Bus Study ridechecks, ridership on Route 57 is approximately 9870 passengers per day, with about 27 percent (2660) of those trips involving a Green Line transfer at Kenmore. Based upon West Bus Study ridechecks, ridership on Route 301 is approximately 2220 per day. Total ridership on the two routes combined is 12,090 per weekday

  (Headways on Route 57 are 6 minutes in the AM and PM peaks, 8 to 9 minutes during the mid-day and school peak periods, and 15 minutes in the early morning and night periods. Route 301 is essentially a peak period only express service with 6 to 7 minute headways in the peak periods, lengthening to 15 to 20 minute headways at the fringes of the peaks.)

- *Alternative 1 - Existing Route 57 and 301 Services with a Free Transfer between Route 57 and the Green Line at Kenmore* As previously stated, about 27 percent of all Route 57 trips involve a transfer to or from the Green Line at Kenmore. At present, the MBTA charges full fare for each transfer. Were the transfer charge to be eliminated with service maintained at current levels, fares for transfer trips would effectively be reduced by 50 percent. This would result in an approximate 17.5 percent increase in transfer trips, or an increase of 472 trips per day. Combined ridership under this scenario on Routes 57 and 301 would be 12,560 per day, for an overall increase of 3.9 percent.

- *Alternative 2 - Trolley Service between Watertown Square and Park Street* Under this alternative, Routes 57 and 301 would be replaced by light rail service over all of the old A-line alignment. All current Route 57 and 301 riders would be directly served by the new A-line service. Trolleys would operate at 7 minute headways in the AM peak, 10 minutes in the PM peak, and at 14 to 15 minute headways in all other periods.

  Surface ridership on the A-line configured in this manner would be approximately 13,120 per weekday, or 8.6 percent higher than on current bus services, and the highest for any of the alternatives examined. In total, up to 1090 additional trips would be attracted by the lower A-line fare, up to 560 trips attracted by the elimination of the transfer, but 620 trips lost due to the longer headways on the trolley service versus current bus services (see also Table A-7). Of the 13,120 surface riders, approximately 43 percent would travel beyond Kenmore Station into the central subway (see Attachment A3).

Table A-7

WATERTOWN TROLLEY ANALYSIS
Impacts of Service Characteristics on Ridership

	Alt 0 Existing Bus Services (Rts 57 & 301)	Alt 1 Existing Bus with Free Transfer	Alt 2 Trolley to Watertown Sq without Route 301	Alt 3 Trolley to Newton Corner without Route 301	Alt 4a Trolley to Oak Square without Route 301	Alt 4b Trolley to Oak Square with Route 301	Alt 5 Trolley to Brighton Ctr with Route 301	Alt 6 Trolley to Union Sq with Route 301
Base Ridership	12,090	12,090	12,090	12,090	12,090	12,090	12,090	12,090
Impact of Service Changes on Surface Ridership (A-line and Substitute Local Bus)								
Service Coverage Difference	--	--	--	-1,090	--	--	--	--
Fare Differential	--	470	1,090	1,000	800	650	410	220
Elimination of Kenmore Transfer	--	--	560	500	390	390	290	150
Substitute Bus Headways	--	--	--	--	-160	-160	-20	-40
Impostition of Transfer with Sub Bus	--	--	--	--	-2,030	-1,730	-2,420	-3,130
Longer A Line Headways	--	--	-620	-810	-1,370	-1,580	-1,260	-870
SUBTOTAL (Surface Linked Trips)	**12,090**	**12,560**	**13,120**	**11,690**	**9,720**	**9,660**	**9,090**	**8,420**
Subway Increase	--	--	1,250	1,180	1,120	1,040	1,020	1,040
TOTAL LINKED TRIPS (Surface plus Subway Increase):	**12,090**	**12,560**	**14,380**	**12,880**	**10,830**	**10,700**	**10,100**	**9,450**
Sub Bus/A-line Transfers	--	--	--	--	1,080	1,020	1,450	1,910
TOTAL UNLINKED TRIPS (Surface plus Subway Increase):	**12,090**	**12,560**	**14,380**	**12,880**	**11,910**	**11,720**	**11,550**	**11,360**

Note: A linked trip is one complete trip from origin to destination, irrespective of the number of transfers made or modes used. An unlinked trip is a trip made only on the service in question, and does not consider other modes or services used as part of the overall trip. For example, one linked trip from Watertown Square to Downtown Boston on Route 57 to the Green Line would involve two unlinked trips: one on Route 57, and one on the Green Line.

In addition to surface ridership, additional Central Subway ridership would be attracted by the addition of A-line service. For this alternative, about 1250 such trips would be attracted. Including both surface ridership and additional subway ridership, 14,370 daily trips would be attributable to the A-line, an 18.9 percent increase over current bus ridership.

- *Alternative 3 - Trolley Service between Newton Corner and Park Street* With Routes 57 and 301 replaced by a trolley operating between Newton Corner and Park Street, traffic problems at Newton Corner could be avoided, but a number of current Route 57 riders in the vicinity of Watertown Square would be left without service. As of the Fall of 1984, 1600 of 9870 (16.2 percent) Route 57 riders boarded or disembarked at Watertown Square, with 530 of these trips involving a transfer between Route 57 and Route 59, 70 or 71. Assuming a 1/2 mile walk distance for rail service and a 1/4 mile walk distance for bus service, almost 50 percent of those riders now walking to or from Route 57 at Watertown Square would also be within walking distance of the Green Line (520 trips). The remaining 1090 daily trips would no longer be directly served. (The elimination of Route 301 would have no direct impact since it currently does not serve Watertown Square.) Headways on the A-line would be 8 minutes in the AM peak, 11 minutes in the PM peak, and 13 to 15 minutes during other periods.

  A-line surface ridership for this alignment would be 11,700 trips per weekday. Compared to the base case, 1090 trips would be lost due to location of the outer terminal at Newton Corner, up to 1000 trips gained due to the lower fare, 500 trips gained due to the elimination of the transfer, and 810 trips lost due to longer trolley headways. In total, surface ridership would be 3.2 percent lower than with current bus services. However, as with the previous alternative, ridership would also increase in the Central Subway (in this case by 1180 trips per day). When both surface ridership and subway increases are considered, transit ridership would increase 790 trips per day to 12,880, or 6.6 percent, over current levels.

- *Alternative 4a - Trolley Service between Oak Square and Park Street without Route 301* Under this alternative, trolley service would operate between Park Street and Oak Square at 10 to 14 minute headways. Both Route 57 and Route 301 would be eliminated, but substitute local service would be provided between Oak Square and Watertown Square through an extension of Route 64. Surface trolley ridership would be 9570 and bus ridership on the Oak Square to Watertown Square segment of Route 64

would be 1220 trips per weekday, with 1080 of the substitute bus riders transfering to the A-line at Oak Square. Combined ridership on the A-line and substitute bus service would be 10,790 trips per weekday, which would be 1300 trips per day or 10.8 percent below current bus ridership levels on Route 57 and 301. Including a 2.3 percent increase (1110 trips) in subway ridership, total ridership attributed to the alternative would be 1.5 percent lower than the base case.

Most of the decline in surface ridership on this alternative is caused by the low level of service on the substitute bus and the imposition of a transfer on many riders who currently do not transfer. As of the Fall of 1984, 3060 daily Route 57 trips included travel on the segment of the route between Watertown Square and beyond walking distance of Oak Square. Of these trips, 830 at most involved a transfer to the Green Line; with this alternative, 2750 would be required to transfer.

On Route 301, 1180 existing trips involve trip ends between Newton Corner and Oak Square. Of these, about 150 would be within 1/4 mile of other express service at Newton Corner and 840 within 1/2 mile walking distance of the A-line, but the other 190 daily trips would be served instead by the substitute service and the A-line. At present, none of these trips involve a transfer at Kenmore, but with this alternative, all would require a transfer to the A-line at Oak Square. In addition to the imposition of the transfer, service levels would also be significantly lower. On Route 64, peak period headways would be 20 minutes and off-peak headways 30 minutes (compared to six to 15 minute headways on Route 57). On the Green Line, A-line headways at Oak Square would be 11 to 15 minutes, versus two minutes or less at Kenmore. As a result, total wait times would increase from three to 12 minutes, to 17 to 23 minutes. Increases of this magnitude would result in the loss of 2190 of the existing 3410 riders on the Oak Square to Watertown Square segments of Routes 57 and 301.

- *Alternative 4b - Trolley Service between Oak Square and Park Street with Partial Route 301 Service Retained* In this alternative, trolley service would operate at 13 to 15 minute headways throughout the day. Route 301 service between Oak Square and downtown Boston would be retained at current service levels, but service between Oak Square and Brighton Center would be terminated. Route 57 service would also be terminated, with substitute bus service provided between Oak Square and Watertown Square through an extension of Route 64, as in Alternative 4a. Surface trolley ridership and substitute bus ridership with Route 301 retained would be lower than in the Alternative 4a at 8020 and 1170 trips per weekday,

respectively. However, when Route 301 ridership (1490) is considered, total surface ridership at 10,680 would be essentially the same.

As with the previous alternative, a significant amount of ridership is lost due to the imposition of a transfer at Oak Square, the increased transfer time, and the longer headways on Route 64. In this case, the imposition of the transfer results in a loss of 1730 existing riders, and the lower substitute bus headways a loss of 160 riders between Watertown Square and Oak Square. These losses are only partially offset by an increase of 870 riders between Oak Square and Park Street due to the re-introduction of A-line service. Including the subway increase of 1070 trips per day, ridership with this alternative would be 3.5 percent lower than with the continuation of current services.

- *Alternative 5 - Trolley Service between Brighton Center and Park Street* With this alternative, trolleys would operate at 13 to 15 minute headways throughout the day between Brighton Center and Park Street. Route 301 would be retained, and Route 57 would also continue to operate, but only between Watertown Square and Brighton Center. With this configuration, surface ridership on the A-line is estimated at 5910 trips per day and the increase in subway ridership at 1020 trips per day. Ridership on the shortened Route 57 is estimated at 2400 trips per day, and ridership on Route 301 is estimated to remain at 2220 trips per day. Total ridership attributable to this alternative therefore would be 11,550 trips per day, or 4.4 percent lower than the base case.

With this alternative, most of the surface ridership loss is due to the imposition of a transfer at Brighton Center. In this case, the imposition of the transfer and the increased wait time due to longer Green Line headways at Brighton Center than at Kenmore results in a loss of 2420 existing trips.

- *Alternative 6 Trolley Service between Union Square and Park Street* For this alternative, A-line service between Union Square would operate at 12 to 15 minute headways throughout the day. Route 301 would be retained, but Route 57 would be shortened to operate only between Watertown Square and Union Square. Both Route 57 and 301 would operate at their current service levels. With this configuration, surface A-line ridership between Kenmore and Union Square would be 4070 trips per day and the subway increase would be 1040 trips per day. Route 301 ridership would remain at 2220 per day, but ridership on the shortened Route 57 would decrease to 4030 trips per day, including 1910 transfers with the A-line. Total ridership attributable to this alternative would be

11,360, or a 6.0 percent decrease from the base case. As with the previous alternative, most of the decrease is due to the imposition of the transfer with its accompanying longer wait times (in this case at Union Square), resulting in a loss of 2330 existing riders, only partially offset by other gains.

A.4 RIDERSHIP IMPACT OF OTHER OPTIONS

As previously stated, in addition to the above alternatives, an inner terminal at Government Center, trolley reservations, a tunnel in the vicinity of Brighton Center, and traffic signal pre-emption for the trolleys were also considered. The ridership impact of these items would be as follows:

- *Inner Terminal at Government Center* Based upon travel patterns of surface-to-subway riders on other Green Line surface lines, an extension to Government Center would result in an increase in surface ridership of approximately two percent. Depending on the alternative, this would be an increase of from 60 to 260 surface trips per day. The impact on subway-to-subway ridership would be greater, resulting in an increase of approximately 50 percent over and above that between Kenmore and Park Street, or from 520 to 630 trips per day, depending upon the alternative.

- *Signal Pre-emption.* Signal pre-emption would allow trolleys to avoid delays caused by traffic signals at certain intersections. However, in order to avoid serious traffic delays on cross streets, signal pre-emption could not be used at intersections with heavy cross street traffic. In the case of the A-line, most of the signal delays occur at major intersections where signals could not be pre-empted (Union Square, Brighton Center, Oak Square, and Newton Corner). As a result, signal pre-emption of the remaining signals would result in only marginal improvements. For an average one-way trip between Watertown Square and Kenmore Station that takes 24 and 31 minutes, 36 seconds of travel time would be saved. Expected ridership increases would be in the range of less than one percent to two percent, depending upon the time of day.

- *Trolley Reservations.* Trolley reservations between Packard's Corner and Brighton Center would allow trolleys to avoid some traffic delays during peak periods. (During off-peak periods, due to lower traffic volumes, trolleys could operate as fast without reservations as

with them.) In the AM peak period, it is estimated that average operating speeds between Packard's Corner and Brighton Center could be increased from 10.4 mph to 12.8 mph, resulting in a time savings of 87 seconds, or 5.0 percent, per one-way trip. In the school peak, average operating speeds could be increased from 11.6 mph to 12.8 mph, for a travel time savings of 48 seconds, or 2.6 percent. In the PM peak, average operating speeds could be increased from 10.0 mph to 12.8 mph, resulting in a time savings of 106 seconds per one-way trip, or 5.9 percent. Using a peak period travel time elasticity of -0.39, probable ridership increases resulting from these time savings for the AM, school and PM peak periods would be respectively, 2.0 percent, 1.0 percent, and 2.3 percent.

- *Brighton Center Tunnel.* A tunnel from just east of the intersection of Washington/Cambridge/Winship to west of Washington and Foster would avoid delays in the Brighton Center area. Assuming a half mile tunnel without stations and using observed acceleration and deceleration characteristics of the Boeing LRVs, and a maximum speed of 50 mph, the average operating speed through the tunnel would be 29.0 mph, and the average running time 62 seconds. Without the tunnel, operating speeds and run times would be as shown below. Estimated time savings and ridership increases resulting from the tunnel are also shown.

Table A-8
Time Savings/Ridership Increase with Brighton Center Tunnel for Watertown Sq - Kenmore Segment

	Early Morn	AM Peak	Mid-day	School Peak	PM Peak	Evening /Night
Tunnel Segment						
Avg Oper Spd (mph)	11.6	9.6	11.4	10.7	9.2	11.5
Avg Run Time w/o tunnel (secs)	155	188	158	168	196	157
Avg Run Time w/ tunnel (secs)	62	62	62	62	62	62
Time Savings with Tunnel (secs)	93	126	96	106	134	95
Wat Sq - Kenmore						
Avg Run Time (min)	24	29	24	26	30	24
Elasticity	-0.74	-0.39	-0.74	-0.39	-0.39	-0.74
Ridership Increase	***4.7%***	***2.8%***	***4.9%***	***2.2%***	***2.9%***	***4.8%***

• *Overall Impact of Signal Pre-emption, Trolley Reservations and Brighton Center Tunnel.* If all three of the methods of reducing travel time discussed above were implemented, the overall impact would be as shown below.

Table A-9
Total Travel Time Savings/Ridership Increases
(in seconds unless noted)

	Early Morn	AM Peak	Mid-day	School Peak	PM Peak	Evening /Night
Signal Pre-emption	35	35	35	35	35	35
Reservations	0	87	0	48	106	0
Tunnel	93	126	96	106	134	95
TOTAL	128	248	131	189	275	130
One-Way Run Time(min)	24	29	24	31	30	24
% Reduction	8.8%	14.3%	9.1%	10.2%	15.3%	9.0%
Assumed Elasticity	-0.74	-0.39	-0.74	-0.39	-0.39	-0.74
Ridership Increase	***6.5%***	***5.6%***	***6.6%***	***4.0%***	***6.0%***	***6.6%***

ATTACHMENT A1

Sample of Ridership Projection Calculations

Watertown Trolley
Estimated Ridership, Demand-Based Headways & Vehicle Requirements
Alternative 4a: Oak Square - Park Street w/o Route 301

	Early AM	AM Peak	Mid-day	School Peak	PM Peak	Evening/ Night	Total
ESTIMATE SURFACE RIDERSHIP ASSUMING (1) NO CHANGE IN HEADWAYS, AND (2) WATERTOWN SQ - PARK STREET ALIGNMENT SERVES SAME MARKET AS EXISTING BUS ROUTES 57 AND 301.							
Base Ridership							
Route 57							
•In	422	1425	1425	676	567	451	4966
•Out	336	745	886	934	951	1049	4901
•Total	758	2170	2311	1610	1518	1500	9867
Route 301							
•In	48	903	94	4	12	0	1061
•Out	0	212	22	106	703	117	1160
•Total	48	1115	116	110	715	117	2221
Route 57 & Route 301 Combined							
•In	470	2328	1519	680	579	451	6027
•Out	336	957	908	1040	1654	1166	6061
•Total	806	3285	2427	1720	2233	1617	12088
Base Headways							
•Route 57	15	6	9	8	6	15	
•Route 301	15	6	15	20	7	10	
• Green Line @ Kenmore Station	3	2	2	2	2	3	
Increase/Decrease in Market Served by A Line due to Change in Service Coverage							
A. Decrease due to Change in Outer Terminal Location/Retention of Rt 301							
% Inc/Dec due to Service Change							
•Route 57 Market	-31.0%	-31.0%	-31.0%	-31.0%	-31.0%	-31.0%	
•Route 301 Market	-16.0%	-16.0%	-16.0%	-16.0%	-16.0%	-16.0%	
Increase/Decrease							
Route 57 Market							
•In	-131	-442	-442	-210	-176	-140	-1539
•Out	-104	-231	-275	-290	-295	-325	-1519
•Total	-235	-673	-716	-499	-471	-465	-3059
Route 301 Market							
•In	-8	-144	-15	-1	-2	0	-170
•Out	0	-34	-4	-17	-112	-19	-186
•Total	-8	-178	-19	-18	-114	-19	-355
Route 57 & Route 301 Markets Combined							
•In	-139	-586	-457	-210	-178	-140	-1709
•Out	-104	-265	-278	-307	-407	-344	-1705
•Total	-243	-851	-735	-517	-585	-484	-3414
•Change in Surface Mileage	-3.50	-3.50	-3.50	-3.50	-3.50	-3.50	
B. Increase due to Extension of Service to Government Center							
•% Inc/Dec due to Service Change	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
Increase/Decrease							
Route 57 Market							
•In	0	0	0	0	0	0	0
•Out	0	0	0	0	0	0	0
•Total	0	0	0	0	0	0	0

Route 301 Market							
•In	0	0	0	0	0	0	0
•Out	0	0	0	0	0	0	0
•Total	0	0	0	0	0	0	0
Route 57 & Route 301 Markets Combined							
•In	0	0	0	0	0	0	0
•Out	0	0	0	0	0	0	0
•Total	0	0	0	0	0	0	0
•Change in Subway Mileage	0.00	0.00	0.00	0.00	0.00	0.00	

Increase/Decrease in Surface Ridership due to Fare Change

•Route 57 Average Fare			$0.38				
•Route 301 Average Fare			$0.78				
•Green Line Average Fare (in-surface/out-subway)			$0.49				
•Green Line Average Fare (in-subway/out-subway)			$0.46				
•Green Line Average Fare (in-surface/out surface)			$0.35				
Assumed Fare Difference between A Line and:							
•Route 57	-23%	-23%	-23%	-23%	-23%	-23%	
•Route 301	-37%	-37%	-37%	-37%	-37%	-37%	
•Assumed Elasticity	-0.35	-0.35	-0.35	-0.35	-0.35	-0.35	
Total Increase/(Decrease)							
Route 57 Market							
•In	24	80	80	38	32	25	279
•Out	19	42	50	53	53	59	276
•Total	43	122	130	91	85	84	555
Route 301 Market							
•In	5	98	10	0	1	0	116
•Out	0	23	2	12	77	13	126
•Total	5	122	13	12	78	13	242
Route 57 & Route 301 Markets Combined							
•In	29	179	90	38	33	25	395
•Out	19	65	52	64	130	72	402
•Total	48	244	143	103	163	97	797

Increase/Decrease in Surface Ridership due to Elimination of Transfer

Fall 1984 Avg Wait/Transfer Time (Wait Times @ 50 % of Headways)							
•to Green Line	2	1	1	1	1	2	
•to Route 57	8	3	5	4	3	8	
•Plus Walk Between Rt 57 & G.L.	2	2	2	2	2	2	
•Transfer Penalty	5	5	5	5	5	5	
•Total	16	11	13	12	11	16	
Elimination of Transfer							
% Rt 57 Riders Transferring							
•In	25%	25%	25%	25%	25%	25%	
•Out	29%	29%	29%	29%	29%	29%	
•Total	27%	27%	27%	27%	27%	27%	
No. of Rt 57 Riders Transferring							
•In	79	266	266	126	106	84	926
•Out	73	161	192	202	206	227	1061
•Total	151	427	458	328	312	311	1987
Time Saved (@ avg wait time on Green Line + walk time between bus and Green Line + Transfer Penalty)							
•In	9	8	8	8	8	9	
•Out	9	8	8	8	8	9	
•Assumed Elasticity	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	

Total Increase/Decrease							
•In	13	58	51	25	23	13	183
•Out	12	35	37	40	45	36	205
•Total	24	93	88	66	68	50	388

DETERMINE SUBSTITUTE BUS RIDERSHIP & TRANSFERS TO A LINE

Current Riders Not Served by A Line Alignment - Would Have to be Served by Substitute Bus

Is substitute Rt 57 service to be provided? *yes*

Is Route 301 to be retained? *no*

Existing Riders NOT Served by New A Line or Rt 301 (if retained)

Route 57 Market							
•In	131	442	442	210	176	140	1539
•Out	104	231	275	290	295	325	1519
•Total	235	673	716	499	471	465	3059
Route 301 Market							
•In	8	144	15	1	2	0	170
•Out	0	34	4	17	112	19	186
•Total	8	178	19	18	114	19	355
Route 57 & Route 301 Markets Combined							
•In	139	586	457	210	178	140	1709
•Out	104	265	278	307	407	344	1705
•Total	243	851	735	517	585	484	3414

Adjust Substitute Bus Ridership to Account for Assumed Substitute Bus Headways (non-transfer trips only)

•Assumed Sub Bus Headways	30	20	30	20	20	30	
Existing Headways on Routes 57 & 301							
•Route 57	15	6	9	8	6	15	
•Route 301	15	6	15	20	7	10	
Assumed Elasticities							
•Route 57	-0.49	-0.27	-0.19	-0.27	-0.27	-0.49	
•Route 301	-0.49	-0.27	-0.49	-0.32	-0.27	-0.49	
Total Increase/(Decrease)							
Route 57 Market							
•In	-6	-28	-20	-8	-11	-7	-80
•Out	-5	-15	-12	-12	-19	-16	-78
•Total	-12	-42	-32	-20	-30	-23	-158
Route 301 Market							
•In	0	0	0	0	0	0	0
•Out	0	0	0	0	0	0	0
•Total	0	0	0	0	0	0	0
Route 57 & Route 301 Markets Combined							
•In	-6	-28	-20	-8	-11	-7	-80
•Out	-5	-15	-12	-12	-19	-16	-78
•Total	-12	-42	-32	-20	-30	-23	-158

Transfers from Substitute Bus to A Line

•% Ex-57 Riders Transfer Sub Bus to GL	90%	90%	90%	90%	90%	90%	
•# Ex-57 Riders Transfer Sub Bus to GL							
•In	118	398	398	189	158	126	1386
•Out	94	208	247	261	265	293	1367
•% Ex-301 Riders Transfer Sub Bus to GL	100%	100%	100%	100%	100%	100%	
•# Ex-301 Riders Transfer Sub Bus to GL							
•In	8	144	15	1	2	0	170
•Out	0	34	4	17	112	19	186

•Total Transfers before Adjustments							
•In	125	542	413	189	160	126	1555
•Out	94	242	251	278	378	311	1553
Wait Time Adjustment							
Assumed Wait Times							
•to Route 301	8	3	8	10	4	5	
•to Route 57	8	3	5	4	3	8	
•to A Line	7	5	7	7	7	7	
•to Green Line @ Kenmore	2	1	1	1	1	2	
•Walk Time Between Rt 57 & G.L.	2	2	2	2	2	2	
•to Substitute Bus	15	10	15	10	10	15	
•Plus Walk Between Sub Bus & G.L.	1	1	1	1	1	1	
•Assumed Transfer Penalty	5	5	5	5	5	5	
•Assumed Elasticity	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	
Reduction in Transfers due to Increased Wait Time							
Route 57							
•In	-87	-565	-523	-220	-244	-93	-1732
•Out	-69	-296	-325	-304	-410	-216	-1619
Route 301							
•In	-6	-260	-12	0	-3	0	-282
•Out	0	-61	-3	-7	-183	-25	-279
Fare Difference Adjustment							
•Local Bus Average Fare			$0.38				
•Route 301 Average Fare			$0.78				
•Green Line Average Fare (in-subway/out-subway)			$0.46				
•Green Line Average Fare (in-surface/out-subway)			$0.49				
•Green Line Average Fare (in-surface/out surface)			$0.35				
Assumed Fare Difference between Sub Bus and:							
•Route 57	50%	50%	50%	50%	50%	50%	
•Route 301	11%	11%	11%	11%	11%	11%	
•Assumed Elasticity	-0.35	-0.35	-0.35	-0.35	-0.35	-0.35	
Total Increase/(Decrease)							
Route 57 Market							
•In	-7	27	18	3	14	-7	48
•Out	-5	14	11	5	23	-16	31
•Total	-12	41	29	8	37	-23	79
Route 301 Market							
•In	0	-3	0	0	7	1	4
•Out	0	-1	0	-1	-4	-1	-7
•Total	0	-5	-1	0	3	0	-3
Estimated Total Transfers to A Line to/from Substitute Bus							
•In	45	170	150	70	59	47	540
•Out	35	82	92	99	116	111	536
•Total	79	253	242	169	175	158	1075
Total A Line Surface Ridership before headway adjustments							
•In	418	2149	1353	603	516	397	5436
•Out	297	875	811	937	1538	1041	5499
•Total	715	3023	2164	1540	2054	1438	10935

ADJUST HEADWAYS TO MATCH SURFACE DEMAND (ASSUMING ONE CAR TRAINS)

Vehicle Trips Needed						
•Peak Direction	In	In	In	Out	Out	Out
•Max Allowable Passenger Load	130	130	130	130	130	130
•Max Load as % of Total Ons	85%	85%	70%	70%	85%	85%
•Vehicle Trips Needed	2.7	14.0	7.3	5.0	10.1	6.8
•Period Length	1.83	2	5	2	2	7
•Vehicle Trips per Hour	1.5	7.0	1.5	2.5	5.0	1.0
A Line Estimated Cycle Times						
Surface Running Time						
•Route Mileage (round trip)	7.3	7.3	7.3	7.3	7.3	7.3
•Avg Operating Speed	13.6	11.2	13.3	12.5	10.8	13.5
•Round Trip Running Time	32.2	39.1	32.9	35.0	40.6	32.4
Subway Running Time						
•Route Mileage (round trip)	3.8	3.8	3.8	3.8	3.8	3.8
•Avg Operating Speed	13.0	10.4	11.4	10.4	10.4	11.4
•Round Trip Running Time	17.5	21.9	20.0	21.9	21.9	20.0
Surface plus Subway						
•Total Running Time	50	61	53	57	62	52
Cycle Time						
•Cycle Time Contingency Factor	1.1	1.1	1.1	1.1	1.1	1.1
•Layover time	7	7	7	7	7	7
•"Optimum" Cycle Time	62	74	65	70	76	65
Headways, Vehicle Requirements and Revised Cycle Time - based on best fit of "Optimum" Cycle Time & the number of vehicles required.						
•"Optimum" Headway (15 min max)	15	9	15	15	12	15
•Vehicles required	5	9	5	5	7	5
•Headways - Best Fit with Veh Reqmt	13	9	14	14	11	13
•Revised Cycle Time	65	81	70	70	77	65

REVISE SURFACE DEMAND ESTIMATES BASED ON NEW HEADWAYS

Surface Ridership from Step 1							
•In	418	2149	1353	603	516	397	5436
•Out	297	875	811	937	1538	1041	5499
•Total	715	3023	2164	1540	2054	1438	10935
Existing Headways on Routes 57 & 301							
•Route 57	15	6	9	8	6	15	
•Route 301	15	6	15	20	7	10	
Trolley Headway from Step 2							
•A Line	13	9	14	14	11	13	
Increase/Decrease due to Headway Change							
Assumed Elasticities							
•Route 57	-0.49	-0.27	-0.19	-0.27	-0.27	-0.49	
•Route 301	-0.49	-0.27	-0.49	-0.32	-0.27	-0.49	
Total Increase/(Decrease)							
•Route 57	44	-261	-216	-290	-305	86	-943
•Route 301	3	-147	4	11	-108	-17	-253
•Total	47	-408	-213	-279	-413	70	-1197

Revised A Line Surface Ridership after One Iteration							
•In	445	1858	1220	494	413	416	4846
•Out	316	757	731	767	1229	1092	4892
•Total	762	2615	1951	1261	1641	1508	9738

ITERATION TO MATCH HEADWAYS TO SURFACE DEMAND

Iterations: *5*

Surface Ridership from Previous Iteration (Iteration No: 4)							
•In	445	1798	1220	494	392	416	4765
•Out	316	733	731	767	1164	1092	4803
•Total	762	2531	1951	1261	1556	1508	9569
Trolley Headway from Previous Iteration							
•A Line	13	10	14	14	13	13	
Calculate New Headway based on Surface Ridership from Previous Iteration							
Vehicle Trips Needed - This Iteration							
•Peak Direction	In	In	In	Out	Out	Out	
•Max Allowable Passenger Load	130	130	130	130	130	130	
•Max Load as % of Total Ons	85%	85%	70%	70%	85%	85%	
•Vehicle Trips Needed	2.9	11.8	6.6	4.1	7.6	7.1	
•Period Length	1.83	2	5	2	2	7	
•Vehicle Trips per Hour	1.6	5.9	1.3	2.1	3.8	1.0	
A Line Estimated Cycle Times							
•Optimum Cycle Time	62	74	65	70	76	65	
Headways, Vehicle Requirements and Revised Cycle Time - based on best fit of "Optimum" Cycle Time & the number of vehicles required - This Iteration							
•"Optimum" Headway (15 min max)	15	10	15	15	15	15	
•Vehicles required	5	8	5	5	6	5	
•Headways - Best Fit with Veh Reqmt	13	10	14	14	13	13	
•Revised Cycle Time	65	80	70	70	78	65	
Surface Ridership Increase/Decrease due to Headway Change - This Iteration							
Assumed Elasticities							
•A Line	-0.49	-0.32	-0.49	-0.32	-0.32	-0.49	
Total Increase/Decrease							
•Inbound	0	0	0	0	0	0	0
•Outbound	0	0	0	0	0	0	0
•Total	0	0	0	0	0	0	0
Revised Surface Ridership Estimate							
•Inbound	445	1798	1220	494	392	416	4765
•Outbound	316	733	731	767	1164	1092	4803
•Total	762	2531	1951	1261	1556	1508	9569

INCREASE IN SUBWAY RIDERSHIP DUE TO ADDITIONAL SUBWAY SERVICE RESULTING FROM ADDITION OF A LINE.

•Existing Green Line Headways	1.4	1.4	1.2	1.2	1.6	2
•A Line Headways	13	10	14	14	13	13
•Average Wait Times - Current	0.7	0.7	0.6	0.6	0.8	1
•Average Wait Times - w/ A Line	0.6	0.6	0.6	0.6	0.7	0.9
•Assumed Elasticity	-0.19	-0.27	-0.19	-0.27	-0.27	-0.19

Current Green Line Subway Ridership :	**(Kenmore - Park Street)**						
•Inbound (Northbound)	1316	1889	6330	3995	5951	4107	23588
•Outbound (Westbound)	1103	5260	7423	2775	3947	3445	23953
•Total	2419	7149	13753	6770	9898	7552	47541
Increase in Subway Ridership due to A Line							
•Inbound	24	63	95	85	176	104	547
•Outbound	20	174	111	59	117	87	569
•Total	45	237	206	144	293	191	1117
TOTAL RIDERSHIP ATTRIBUTABLE TO A LINE - SURFACE RIDERSHIP + INCREASE IN SUBWAY RIDERSHIP + SUBSTITUTE BUS RIDERSHIP + ROUTE 301 RIDERSHIP (IF RETAINED)							
•Inbound	521	2048	1489	662	633	573	5926
•Outbound	377	998	950	943	1408	1307	5982
•Total	898	3046	2439	1604	2041	1880	11908

ATTACHMENT A2

Ridership Projections by Time Period

Watertown Trolley Analysis
Demand Estimates
Alternative 0: Base Case - Maintain Existing Routes 57 and 301

- Existing ridership on existing Routes 57 and 301.
- Includes transfer charge between Route 57 and Green Line @ Kenmore.

	Early AM	AM Peak	Mid-day	School Peak	PM Peak	Evening/ Night	**Total**
Existing Bus							
Route 57	758	2170	2311	1610	1518	1500	**9867**
Route 301	48	1115	116	110	715	117	**2221**
Combined Total	**806**	**3285**	**2427**	**1720**	**2233**	**1617**	**12088**
GL/Rt 57 Transfers	205	586	624	435	410	405	**2664**

Watertown Trolley Analysis
Demand Estimates
Alternative 1: Existing Bus Service with Free Transfer Between Route 57 and Green Line

Assumptions:
1. No diversion from Route 301 to Route 57/Green Line due to free transfer.

	Early AM	AM Peak	Mid-day	School Peak	PM Peak	Evening/ Night	**Total**
Existing Bus							
Route 57	794	2271	2420	1688	1592	1574	**10339**
Route 301	48	1115	116	110	715	117	**2221**
Combined Total	**842**	**3386**	**2536**	**1798**	**2307**	**1691**	**12560**
% Δ fr Base Case	**4.5%**	**3.1%**	**4.5%**	**4.5%**	**3.3%**	**4.6%**	**3.9%**
GL/Rt 57 Transfers	241	687	733	513	484	479	**3136**

Watertown Trolley Analysis
Demand Estimates
Alternative 2: Watertown Square - Park Street; Eliminate Routes 57 and 301

Assumptions:
1. A Line fares on average are 23% lower than Route 57 fares and 37% lower than Route 301 fares.
2. Transfer penalty = 5 minutes.
3. Both Route 57 and Route 301 eliminated.

Other Data
A. Surface mileage = 10.8 miles round trip.
B. Subway mileage = 3.8 miles round trip.

	Early AM	AM Peak	Mid-day	School Peak	PM Peak	Evening/ Night	**Total**
A-line							
Surface Ridership	939	3606	2589	1800	2373	1816	**13122**
Subway Increase	42	322	206	135	369	179	**1253**
Total	980	3927	2795	1935	2741	1995	**14375**
Vehicles	6	14	6	6	10	6	
Headways	14	7	14	15	10	14	
Substitute Bus							
Ridership	NA	NA	NA	NA	NA	NA	**NA**
Transfers to/fr GL	NA	NA	NA	NA	NA	NA	**NA**
Headways	NA	NA	NA	NA	NA	NA	
Route 301							
Ridership	0	0	0	0	0	0	**0**
Total Ridership Attributable to Alternative (Surface + Subway							
Increase + Bus):	**980**	**3927**	**2795**	**1935**	**2741**	**1995**	**14375**
% Δ fr Base Case	**21.6%**	**19.6%**	**15.2%**	**12.5%**	**22.8%**	**23.4%**	**18.9%**
Existing Rt 57 and 301 Riders Left Unserved by New Services							
Route 57	0	0	0	0	0	0	**0**
Route 301	0	0	0	0	0	0	**0**

Watertown Trolley Analysis
Summary Of Demand Estimates
Alternative 3: Newton Corner - Park Street; Eliminate Routes 57 and 301

Assumptions:
1. A Line fares on average are 23% lower than Route 57 fares and 37% lower than Route 301 fares.
2. Transfer Penalty = 5 minutes.
3. Outer terminal at Newton Corner results in an 11% reduction in the amount of the Route 57 market served. All of the Route 301 market remains served.
4. Both Route 57 and Route 301 eliminated.

Other Data:
A. Outer terminal at Newton Corner reduces surface mileage by 0.9 miles to 9.9 miles round trip.
B. Subway mileage = 3.8 miles round trip.

	Early AM	AM Peak	Mid-day	School Peak	PM Peak	Evening/ Night	**Total**
A-line							
Surface Ridership	815	3213	2318	1639	2065	1650	**11700**
Subway Increase	39	287	206	144	314	191	**1183**
Total	854	3501	2524	1783	2379	1841	**12883**
Vehicles	5	12	6	6	8	6	
Headways	15	8	14	14	12	13	
Substitute Bus							
Ridership	NA	NA	NA	NA	NA	NA	**NA**
Transfers to/fr GL	NA	NA	NA	NA	NA	NA	**NA**
Headways	NA	NA	NA	NA	NA	NA	
Route 301							
Ridership	0	0	0	0	0	0	**0**
Total Ridership Attributable to Alternative (Surface + Subway							
Increase + Bus):	**854**	**3501**	**2524**	**1783**	**2379**	**1841**	**12883**
% Δ fr Base Case	**6.0%**	**6.6%**	**4.0%**	**3.7%**	**6.6%**	**13.9%**	**6.6%**
Existing Rt 57 and 301 Riders Left Unserved by New Services							
Route 57	83	239	254	177	167	165	**1085**
Route 301	0	0	0	0	0	0	**0**

Watertown Trolley Analysis
Demand Estimates
Alternative 4a: Oak Square - Park Street; Eliminate Routes 57 and 301

Assumptions:

1. A Line fares on average are 23% lower than Route 57 fares and 37% lower than Route 301 fares.
2. Transfer Penalty = 5 minutes.
3. Outer terminal at Oak Square results in a 31% reduction in the amount of the Route 57 market served, and a 16% reduction in the amount of the Route 301 market served.
4. Both Route 57 and Route 301 eliminated.
5. Substitute bus service provided between Oak Square and Watertown Square by extending Route 64.
6. 90% of ex-Route 57 riders and 100% of ex-Route 301 riders will transfer from the substitute bus to the A Line.

Other Data:

A. Outer terminal at Oak Square reduces surface mileage by 3.5 miles to 7.3 miles.
B. Subway mileage = 3.8 miles round trip.

	Early AM	AM Peak	Mid-day	School Peak	PM Peak	Evening/ Night	**Total**
A-line							
Surface Ridership	762	2531	1951	1261	1556	1508	**9569**
Subway Increase	45	237	206	144	293	191	**1117**
Total	806	2768	2158	1406	1849	1699	**10685**
Vehicles	5	8	5	5	6	5	
Headways	13	10	14	14	13	13	
Substitute Bus							
Ridership	91	277	281	199	192	182	**1223**
Transfers to/fr GL	79	253	242	169	175	158	**1075**
Headways	30	20	30	20	20	30	
Route 301							
Ridership	0	0	0	0	0	0	**0**
Total Ridership Attributable to Alternative (Surface + Subway							
Increase + Bus):	**898**	**3046**	**2439**	**1604**	**2041**	**1880**	**11908**
% Δ fr Base Case	**11.4%**	**-7.3%**	**0.5%**	**-6.7%**	**-8.6%**	**16.3%**	**-1.5%**
Existing Rt 57 and 301 Riders Left Unserved by New Services							
Route 57	0	0	0	0	0	0	0
Route 301	0	0	0	0	0	0	0

Watertown Trolley Analysis
Demand Estimates
Alternative 4b: Oak Square - Park Street; Eliminate Route 57; Operate Route 301 to Oak Square Only

Assumptions:

1. A Line fares on average are 23% lower than Route 57 fares and 37% lower than Route 301 fares.
2. Transfer Penalty = 5 minutes.
3. Outer terminal at Oak Square results in a 31% reduction in the amount of the Route 57 market served, and a 16% reduction in the amount of the Route 301 market served.
4. Route 57 eliminated.
5. Route 301 operated terminated at Oak Square.
6. Substitute local bus service provided between Oak Square and Watertown Square by extending Route 64.
7. 90% of ex-Route 57 riders and 100% of ex-Route 301 riders will transfer from the substitute bus to the A Line.

Other Data:

A. Outer terminal at Oak Square reduces surface mileage by 3.5 miles to 7.3 miles.
B. Subway mileage = 3.8 miles round trip.

	Early AM	AM Peak	Mid-day	School Peak	PM Peak	Evening/ Night	**Total**
A-line							
Surface Ridership	731	1637	1879	1188	1135	1447	**8017**
Subway Increase	45	165	206	144	293	191	**1044**
Total	775	1802	2085	1332	1428	1639	**9061**
Vehicles	5	5	5	5	6	5	
Headways	13	15	14	14	13	13	
Substitute Bus							
Ridership	90	249	278	196	174	179	**1166**
Transfers to/fr GL	78	224	239	166	157	155	**1019**
Headways	30	20	30	20	20	30	
Route 301							
Ridership	32	747	78	74	479	78	**1488**
Total Ridership Attributable to Alternative (Surface + Subway							
Increase + Bus):	**898**	**2798**	**2442**	**1602**	**2081**	**1896**	**11716**
% Δ fr Base Case	**11.4%**	**-14.8%**	**0.6%**	**-6.9%**	**-6.8%**	**17.2%**	**-3.1%**
Existing Rt 57 and 301 Riders Left Unserved by New Services							
Route 57	0	0	0	0	0	0	0
Route 301	0	0	0	0	0	0	0

Watertown Trolley Analysis
Demand Estimates
Alternative 5: Brighton Center - Park Street; Eliminate Route 57, Retain Route 301

Assumptions:

1. A Line fares on average are 23% lower than Route 57 fares and 37% lower than Route 301 fares.
2. Transfer Penalty = 5 minutes.
3. Outer terminal at Brighton Center results in a 49% reduction in the amount of the Route 57 market served, and a 80% reduction in the amount of the Route 301 market served.
4. Route 57 eliminated/Route 301 retained.
5. Substitute bus service at approximately Rt 57 headways provided between Watertown Square and Brighton Center.
6. 80% of ex-Route 57 riders will transfer from the substitute bus to the A Line.
7. All current Route 301 riders will continue to ride Route 301.

Other Data:

A. Outer terminal at Brighton Center reduces surface mileage by 5.2 miles to 5.6 miles.
B. Subway mileage = 3.8 miles round trip.

	Early AM	AM Peak	Mid-day	School Peak	PM Peak	Evening/ Night	**Total**
A-line							
Surface Ridership	578	1083	1463	973	709	1109	**5914**
Subway Increase	42	188	194	154	274	169	**1020**
Total	620	1270	1656	1127	983	1278	**6934**
Vehicles	4	5	4	5	5	4	
Headways	14	13	15	13	14	15	
Substitute Bus							
Ridership	193	527	533	402	369	373	**2398**
Transfers to/fr GL	119	315	335	234	220	226	**1449**
Headways	15	6	15	6	6	15	
Route 301							
Ridership	48	1115	116	110	715	117	**2221**
Total Ridership Attributable to Alternative (Surface + Subway							
Increase + Bus):	**861**	**2913**	**2305**	**1639**	**2067**	**1768**	**11553**
% Δ fr Base Case	**6.8%**	**-11.3%**	**-5.0%**	**-4.7%**	**-7.4%**	**9.3%**	**-4.4%**
Existing Rt 57 and 301 Riders Left Unserved by New Services							
Route 57	0	0	0	0	0	0	0
Route 301	0	0	0	0	0	0	0

Watertown Trolley Analysis
Demand Estimates
Alternative 6: Union Square - Park Street; Eliminate Route 57, Retain Route 301

Assumptions:

1. A Line fares on average are 23% lower than Route 57 fares and 37% lower than Route 301 fares.
2. Transfer Penalty = 5 minutes.
3. Outer terminal at Union Square results in a 73% reduction in the amount of the Route 57 market served, and a 100% reduction in the amount of the Route 301 market served.
4. Route 57 eliminated/Route 301 retained.
5. Substitute bus service at approximately Rt 57 headways provided between Watertown Square and Union Square.
6. 70% of ex-Route 57 riders will transfer from the substitute bus to the A Line.
7. All current Route 301 riders will continue to ride Route 301.

Other Data:

A. Outer terminal at Brighton Center reduces surface mileage by 6.7 miles to 4.1 miles.
B. Subway mileage = 3.8 miles round trip.

	Early AM	AM Peak	Mid-day	School Peak	PM Peak	Evening/ Night	**Total**
A-line							
Surface Ridership	425	691	1049	638	450	817	**4071**
Subway Increase	48	175	221	144	258	191	**1038**
Total	473	867	1270	782	708	1008	**5108**
Vehicles	4	4	4	4	4	4	
Headways	12	14	13	14	15	13	
Substitute Bus							
Ridership	328	886	879	681	619	638	**4031**
Transfers to/fr GL	162	410	437	304	287	309	**1910**
Headways	15	6	15	6	6	15	
Route 301							
Ridership	48	1115	116	110	715	117	**2221**
Total Ridership Attributable to Alternative (Surface + Subway Increase + Bus):	**849**	**2867**	**2265**	**1573**	**2042**	**1763**	**11360**
% Δ fr Base Case	**5.4%**	**-12.7%**	**-6.7%**	**-8.5%**	**-8.5%**	**9.0%**	**-6.0%**
Existing Rt 57 and 301 Riders Left Unserved by New Services							
Route 57	0	0	0	0	0	0	0
Route 301	0	0	0	0	0	0	0

ATTACHMENT A3

Surface-to-Subway Ridership Patterns on the A-Line
Versus on Other Green Line Branches

SURFACE TO SUBWAY RIDERSHIP PATTERNS ON THE A-LINE VERSUS ON OTHER GREEN LINE BRANCHES

At present, 27 percent of all Route 57 passengers transfer to the Green Line for travel to and from points east of Kenmore Station. On the B, C and D-line branches of the Green Line, approximately 75 percent of all passengers travel to or from points east of Kenmore Station. Initially, this would seem to indicate that a large number of potential riders are not being attracted due to the lack of through service. However, closer analysis shows that most of the "missing" riders instead already ride other MBTA routes that they find preferable, with the greatest share of these riders using express service operating on the Mass Pike (MBTA Routes 301, 302 and 304). Further, given the choice, most of these riders would continue to use these services even with the restoration of A-line service.

Factors Influencing Surface/Subway Split

On existing Green Line branches, the proportion of riders going into the subway declines as the distance to Kenmore Station increases. It is, therefore, to be expected that Route 57 would have relatively fewer trips into the subway than the B or C-lines, which are shorter. Furthermore, Route 57 buses are not supposed to pick up inbound passengers between Packard's Corner and Kenmore Station. Since this is the segment closest to the subway, it would be expected to have the highest proportion of subway riders. Elimination of this section from Route 57 makes the average percent of subway ridership on that line even lower than it would be otherwise.

Because of the difference in fare structure on Route 57 and the B-line, and the fact that the B-line runs directly into the subway, some surface-to-subway passengers with origins nearest to Route 57 use the B-line. At the same time, some surface-only passengers with origins nearest to the B-line use Route 57. Both of these shifts raise the proportion of surface-to-subway riders on the B-line and surface-only riders on Route 57.

Comparision of A-line and B-line Surface/Subway Splits

To test the reasonableness of the surface/subway ridership split for A-line projections, the segment of the A-line from Packard's Corner to Oak Square was compared with the segment of the B-line from Packard's Corner to Boston College, both of which end approximately four miles from Kenmore Station. CTPS ridership counts indicate that in the morning peak period, about 77 percent of B-line riders who

board between Boston College and Packard's Corner have destinations east of Kenmore Station. Projections for the A-line indicate that with service through to Watertown Square, 1,980 passengers would board between Oak Square and Packard's Corner between 7:00 and 9:00 AM. Of these, 1,210, or 61 percent would travel to subway points east of Kenmore. These figures do not include adjustments for diversions of present B-line riders to the A-line, and present Route 57 riders to the B-line. With these adjustments, A-line peak period boardings between Oak Square and Packard's Corner would rise to 2,340, of which 1,650, or 71 percent, would travel to subway points east of Kenmore. These shifts would also reduce the proportion of B-line riders travelling east of Kenmore to 72 percent.

Operation of Route 57 buses instead of A-line trolleys also has a greater impact on surface-to-subway ridership than on surface-only ridership, since the transfer is imposed on surface-to-subway riders only. Restoration of A-line service would, therefore, result in greater increases in surface-to-subway ridership than in surface-only ridership. If there were significant errors in the demand estimation method, they would be most likely to result in surface-to-subway figures too low compared to surface-only figures. Since the above analysis indicates that the proportions for comparable segments of the A and B-lines would be nearly equal, there is no indication that any significant group of potential A-line riders has not been considered by the demand method.

APPENDIX B OPERATING COST ESTIMATION

B.1 SUMMARY OF COST METHOD

Operating costs for the alternatives examined in this study were estimated using standard procedures developed at CTPS and explained in further detail below. The formulas used include cost components that would be incurred as a direct result of providing the services in question, but exclude fixed costs that would be incurred regardless of whether or not the services in question were operated.

The most recent CTPS cost formulas were prepared in 1986, using data from calender year 1984, because that was the latest year for which final cost reports were then available from all departments of the MBTA. The basic source of all MBTA cost information is the Responsibility Accounting System (RAS). Under the RAS, the various offices, departments, and directorates in the MBTA are subdivided along the lines of related work tasks into approximately 100 "Responsibility Areas," each of which is identified by a three-digit number. Every cost incurred in operating the MBTA is charged to one of roughly 500 "Work Functions," each of which is identified by a four-digit number. At any time, each MBTA employee reports to only one Responsibility Area, but an employee may incur costs in several different Functions. Costs charged to each Function are subdivided into Labor, Materials, Services, and Other, as appropriate. Costs are initially reported monthly, then consolidated into annual reports.

The number of Functions to which costs are charged varies among Responsibility Areas, but for most it is less than 25. More than one Responsibility Area can charge costs to a given Function, but the total number of Responsibility Areas charging costs to any Function is usually ten or less.

Some Functions are, by definition, incurred only in providing one form of service. For example, all costs for Function 2706-Repair and maintenance of bus engines, pertain only to bus service. Other functions include costs related to two or more forms of service, or to the overall operation of the MBTA. For reports requiring fully-allocated cost breakdowns, various formulas are used to distribute costs not directly identifiable with one form of service.

In developing the CTPS cost formulas, the formulas used by the MBTA for assigning shares of each cost function to each service were examined. Adjustments were made as necessary to ensure that the CTPS formulas would represent variable costs. For purposes of deriving cost formulas a manageable number of variables was obtained by examining expenses accounting for about 90 per-

cent of the total for each mode. The remaining 10 percent of costs consist of a large number of items that individually account for very small percentages of total cost. These costs were not analyzed in as fine a detail as the costs in the 90 percent group, but the CTPS cost formula for each mode includes a factor to account for variable costs falling in the 10 percent category.

Within the 90 percent of costs analyzed, an item-by-item determination was made as to whether each cost was fixed or variable, and fixed costs were excluded from further analysis. Variable costs were then subdivided according to the unit of service with which each was most closely related, such as vehicle-miles, vehicle-hours, etc.

Expenses for certain functions, particularly in maintenance categories may fluctuate significantly from year-to-year, so results from a single year could significantly overstate or understate typical costs. For such functions, the cost trends over several years were examined and adjustments made as necessary. Whenever possible, large one-time expenses, such as those for vehicle retro-fitting programs were identified and excluded from the formulas.

B.2 SUMMARY OF BUS COSTS

Units of service used in the bus cost formulas were bus-hours, bus-miles, total number of buses required for the service, including spares, and the number of buses used on the route during the weekday peak-period.

B.2.1 Bus-Hour Costs

These consist of all wage and fringe-benefit costs incurred for bus drivers for operation of the service in question. In 1984, the top hourly straight-time rate for bus drivers was $13.31. New drivers start at 75 percent of the maximum rate, or $9.98. In 1984, the average full-time driver was paid at 94 percent of maximum or $12.51. Part-time drivers are paid at 75 percent of maximum regardless of length of service. For the cost calculations, the mix of full-time and part-time drivers was assumed to be the same as in 1984, or 80.6/19.4. This resulted in a basic average wage of $12.02. The basic day for full-time bus drivers is 7 hours, 50 minutes of working time. This can take place within a maximum span of 13 hours, but "spread premium" pay is required for work after the tenth hour. Overtime is paid for assignments with more than the basic number of work hours. In 1984, spread premiums, scheduled overtime pay, and a distribution of the costs for stand-by or "cover" drivers not actually used in service raised the effective average wage by $0.32 per hour. Unscheduled overtime caused by traffic delays added another $0.19 per hour. The effective hourly wage exclusive of fringe benefits was therefore $12.53.

The MBTA's fringe benefits expenses, which are directly related to labor expenses, include Social Security taxes; contributions to the retirement fund; pay for vacations, holidays, and sick leave; premiums for workmen's compensation insurance, accident and health insurance, and unemployment insurance; and costs of providing uniforms. Although the insurance premiums do not vary as directly with labor expenses as do costs such as Social Security, they are influenced by the general size of the workforce, which in turn is influenced by the amount and type of service provided.

In 1984, the ratio of total expenditures in the MBTA operating budget for the fringe benefits described above to total wages paid from the MBTA operating budget was 55%. For bus-hour cost calculations, this was reduced to 54% to reflect some benefits not paid to part-time employees. This resulted in a total effective hourly wage rate of $19.30. It should be noted that a figure of about $28.00 per hour, used in some other formulas, includes factors for average layover and deadheading time and is applied to revenue hours only. In the CTPS formula the cost factor is applied to the sum of revenue and non-revenue hours. This provides more accurate estimates for individual routes on which the proportion of revenue and non-revenue hours differs from the average. On a systemwide basis, the same results are obtained by either formula.

The $19.30 per hour figure was multiplied by total operator-hours for each alternative, including line-haul time, layover time, deadhead time, and any other time between trips that would be too short to use as unpaid breaks. For the base-case options, driver-hours were calculated from actual assignments as of 1984, with adjustments for changes in service since then. However, the mix of full-time and part-time drivers for each route was assumed to equal the system average rather than the actual mix for that route. This is because the number of part-time drivers at any time is determined largely by labor considerations unrelated to specific routes.

B.2.2 Bus Mile Costs

These consist of expenses for fuel, maintenance tasks related more closely to mileage than to time, and liability costs. Each of these is explained in more detail below. Fringe benefit distributions were added to the maintenance and liability costs. All cost formulas use total revenue and non-revenue miles.

B.2.2.a Fuel

In 1984, the MBTA paid $6,692,528 for 7,009,655 gallons of diesel fuel for buses, or $0.955/gallon. To this was added $371,051 in fuel taxes not reimbursed by the state, or $0.529/gallon. Total bus mileage was 23,860,291, or just over 3.4 miles per gallon, resulting in a fuel cost per mile of $0.296.

B.2.2.b Mileage-Based Maintenance Costs

In the bus cost formula, these include corrective maintenance of bodies and related equipment, engines, electrical equipment, miscellaneous air equipment, air conditioning, and wheelchair lifts. They also include emergency wrecker service; cosmetic repairs; and servicing (fueling, checking oil, etc.) Also included are repairs to vandalism damage, tire repair and rental, and prorated shares of expenses for supervision, tools, and miscellaneous materials. In 1984 the total for these costs incurred at all operating garages plus the Everett shops was $20,697,620, or $0.868 per bus mile.

B.2.2.c Liability Costs

These include expenses for settlement of accident claims, and related expenses such as conducting investigations, labor and expenses for trial work, and related administrative and office expenses. Liability costs can vary significantly from year to year due to differences in numbers of accidents and amounts of settlements. Much of the cost paid in any given year is related to accidents occuring in prior years. An examination of long-range trends showed the 1984 bus liability costs to be representative, however. The total cost of liability items listed above was $3,705,535, or $0.155 per bus mile.

B.2.2.d Recap-Bus Mile Costs

In summary, total bus mile costs were as follows:

Fuel	$0.296
Mileage-Based Maintenance	0.868
liability	0.155
Total	$1.319, rounded to $1.32.

B.2.3 Annual Vehicle Costs

These consist of maintenance functions that are performed more on the basis of time than of mileage. They include inspection, preventive maintenance, cleaning, shifting of vehicles in garage areas, and prorated expenses for supervision, tools, and miscellaneous materials. In 1984 these expenses totalled $3,221,398. During the year, there was an average of 790 buses in the active fleet, including both those scheduled and serviceable spares. This resulted in an average annual vehicle cost of $4,078 per bus, rounded up to $4,100 in the formula.

B.2.4 Peak Vehicle Costs

These differ in their distribution base from annual costs only in that they are distributed over weekday maximum vehicle requirements, excluding spare vehicles. Components of peak

vehicle cost are on-line superintendence, dispatching, and vault-pulling.

B.2.4.a On-line Superintendence

These costs were derived from Work Function 1220-Inspectors and Chief Inspectors for the Arborway, Cabot and Salem Street Rating Stations, with an addition of fringe benefits. In 1984, the expenses for these rating stations totalled $4,385,870 for supervising an average of 465 weekday peak vehicles, or $9,432 per peak vehicle per year. This was rounded up to $9,500 in the formula.

B.2.4.b Dispatching Cost

This consisted of the bus share of Work Function 1222-Surface Lines Dispatching, including fringe add-on. In 1984, this Function Cost $255,334 for 718 weekday peak-buses, or an average of $355. This was rounded off to $350.

B.2.4.c Vault-Pulling Cost

This represents the expense of removing fares from buses and transporting them to a counting area, but not the counting cost itself. In 1984, the bus share of vault-pulling cost, including fringe add-ons, was $847,853 for 718 peak buses, or an average of $1,181, rounded off to $1,150.

B.2.4.d Recap-Peak Vehicle Costs

In summary, total peak vehicle costs per year were as follows:

On Line Superintendence	$9,500
Dispatching	350
Vault-Pulling	1,150
Total	$11,000

B.2.5 Recap-Complete Bus Cost Formula

The bus cost formula used for all alternatives was as follows:

($19.30) x (Annual Bus-hours, revenue and non-revenue)

+ ($1.32) x (Annual Bus-miles revenue and non-revenue)

+ ($4,100 per year) x (Total vehicles required for route, including spares)

+ ($11,000 per year) x (Weekday peak vehicle requirement for route)

A factor of 10% was added to the results to account for variable costs not specifically covered in the formula.

B.3 SUMMARY OF LIGHT RAIL COSTS

Units of service used in Light Rail cost formulas were car-hours, car-miles, total number of vehicles required for the service, including spares, and the number of cars used on the route during weekday peak periods. These units are analogous to those used for buses. In addition to these, factors were included for maintenance and operation of fixed facilities that would be required for operation of A-line service but would not be needed without A-line service. In this case, the service unit for all fixed-family costs was route-miles, but the more general CTPS formula includes other units, where appropriate.

Route 57 bus service takes surface-subway passengers only as far as Kenmore Station, where they must transfer to the Green Line. A-line cars would run through the subway at least as far as Park Street. Therefore, part of the cost of A-line service is for direct replacement of Route 57, and part for operation of new direct subway service to the CBD. Costs for surface and subway expenses for the A-line were calculated separately.

In estimating costs, it was assumed that the inner terminal would be Park Street. For Alternative 2, A-line service to Watertown Square, it was assumed that cars would be based at the Watertown carhouse, and that there would be no deadheading costs. For all other A-line alternatives it was assumed that cars would be based at the new Lechmere yard now under design. Cost estimates for Alternatives 3 through 6 include operation of cars between Lechmere and Park Street at all times that headway changes require increases or decreases of the number of A-line cars in service. Any other change-outs of vehicles were assumed to be done by swapping cars with other routes at Park Street. Costs of running cars between Park Street and Lechmere were included in the subway cost component.

B.3.1 Car-Hour Costs

These consist of all wage and fringe benefit costs incurred for light rail motormen for operation of the service in question. In 1984, the base cost year, part-time operators were not used

for light rail service, but they now are. For purposes of analysis, it was assumed that the proportion of part-time operators would be the same for light rail as for bus, i.e., 19.4 percent. bus or light rail. All service for A-Line alternatives was assumed to be operated with single cars. Two-car trains with the same number of cars would reduce hourly costs slightly, as conductors are paid less than motormen, but at most times this would cause excessively long headways.

In 1984, the top hourly wage for Green Line motormen was $13.46. The pay differential compared to bus drivers is the result of an agreement reached in the 1940s when conductors were eliminated from the first cars of trolley trains. Including factors for full-time labor below the maximum rate, and for part-time labor, the basic average wage for light rail motormen would be $12.15 per hour.

Use of only full-time labor in 1984 resulted in much higher actual cost for scheduled overtime, spread premiums, and cover time for light rail than for buses. For purposes of analysis, it was assumed that with similar proportions of part-time labor these costs would be the same for light rail as for bus, resulting in an add-on of $0.32 per hour.

The average cost of traffic delays is much higher for light rail service on streets than for bus service. This is a result of the inability of light rail vehicles to move around obstacles in their way. In 1984, delays added an average of $0.90 per hour to operating costs for surface light rail lines. This figure is an average for both service on reservation and unprotected street-running. Based on past experience, the A-Line would have above-average expenses for delays. However, lacking more precise information, the $0.90 figure was used in the analysis. The effective hourly wage excluding fringes then became $13.37 per hour. To this was added a 54% fringe-benefit factor, bringing the total to $20.59 for on-street service. For subway operations, the traffic delay factor was excluded, resulting in an hourly cost of $19.20.

B.3.2 Car-Mile Costs

These consist of expenses for electric power, trolley wire maintenance, mileage-based vehicle maintenance, and liability costs.

B.3.2.a Electric Power Costs

These include expenses for purchase of propulsion power, plus operation and maintenance of power substations. Vehicle-mileage was assumed to be the appropriate basis for distribution of substation costs, in that car-mileage has a direct impact on power output, which in turn affects wear and tear on power system equipment. Electric power costs were assumed to include all

expenses in Responsibility Area 371 - Power Systems and Equipment, except for non-propulsion power and special projects. A fringe benefit distribution was added to the labor components in this area. In 1984, MBTA light rail service included a mixture of Boeing LRV's and PCC cars. Wherever used in this memo, "LRV" refers to the Boeing Light Rail Vehicle, although all Green Line cars are classified generically as light rail vehicles. Based on reports for lines operated exclusively with one type of vehicle or the other, and on relative costs for various segments in prior years, factors were developed for power cost by vehicle type by line segment.

For purposes of analysis, power expenses used are those for LRV's. The new Type 7 cars currently being added to the Green Line fleet are known to have substantively higher power consumption rates than the LRV's, so estimates based on LRV's are conservative. In 1984 power costs included in the formula for surface operation totaled $2,098,000, of which an estimated $1,469,000 was attributable to 1,030,000 miles of surface LRV operations, or an average of $1.43 per car mile. Similar calculations for subway service showed $1,366,000 for 1,471,000 car-miles, or $0.93 per car-mile. The power cost differential for subway and street service results from a combination of more frequent starts and stops in street service, and from lower efficiency of the power distribution system on the street segments.

B.3.2.b Trolley Wire Maintenence

These expenses included costs for repair and maintenance of trolley wires, emergency power service, and emergency crew standby, plus fringe benefit add-ons. Wear and tear on trolley wires varies more or less directly with car miles, but the wear rate is significantly higher with pantographs (used on LRV's) and Type 7's than with PCC trolley poles. In the analysis, separate factors were developed for PCC cars and LRV's based on results on lines where their use was distinguishable in 1984. In the cost formula, wire maintenance was $0.29/car-mile for LRV's in streets, based on expenses of $307,000 attributed to 1,030,000 car-miles. For subway operations, it was necessary to use an average for subway and Highland Branch service because of the cost accounting system. This resulted in $527,867 attributed to 2,953,000 car-miles, or an average of $0.18. The higher cost for street service reflects the necessity of working around street traffic.

B.3.2.c Mileage-Based Vehicle Maintenance

The expenses used in the analysis are those for LRV's. Type 7 cars have been used in revenue service only since July 1986. As yet there is insufficient data to determine their long-range maintenance cost characteristics. Although it is anticipated that they will be less than those of LRV's, to date the Type 7's still have a significant in-service failure rate. For purposes

of analysis, it was assumed that maintenance cost savings for Type 7's would largely be offset by increased power consumption.

Expenses included in mileage-based vehicle maintenance were those for Function 2571-Maintenance of LRV's, and 2572-Vandalism Damage Repair-LRV's, plus pro-rated shares of costs for supervision, tools, and miscellaneous materials, and fringe-benefit add-ons to labor components. This resulted in a cost of $1,796,000 for 3,763,000 LRV-miles or an average of $0.48 per mile.

B.3.2.d Liability Costs

The components of liability costs for Light Rail are the same as those described for bus service. Because of some unusually large accident claim settlements, 1984 light rail liability costs were believed to be non-representative based on a five-year trend. Therefore, 1983 expenses were used for this item. This resulted in a cost of $0.08/car-mile for off-street operation, based on expenses of $286,000 and 3,669,000 car-miles, and $0.52/mile for reservation and in-street operation based on $910,000 of expenses for 1,751,000 miles of operations. From past experience it appears that the A-Line would have an accident rate higher than the average for existing surface branches. Therefore, A-Line liability cost would be even higher than predicted by the formula.

B.3.2.e Recap of Car-Mile Costs

The components of car-mile costs used in the formula were as follows:

	Surface	Subway
Electric Power	$1.43	$0.93
Trolley Wire Maintenance	0.29	0.18
Mileage Maintenance of Cars	0.48	0.48
Liability	0.52	0.08
Total	$2.72	$1.67

B.3.3 Annual Vehicle Cost

This consists of the time-based components of vehicle maintenance. For LRV's this includes inspection, preventive maintenance, cleaning, shifting of vehicles in carhouse areas, pro-rated shares of expenses for supervision, tools and miscellaneous materials, and fringe-benefit add-ons to labor components. In 1984, these expenses totalled $7,606,000, for an average fleet of 122 LRV's, or $62,300 per car. In the formula, this was rounded off to $62,000.

B.3.4 Weekday Peak Vehicle Costs

For light rail these include dispatching and vault-pulling. Dispatching costs include allocations of Function 1312-Rail Lines Dispatching and 1222-Surface Dispatching, plus a fringe benefit cost distrubiton. In 1984, these costs totalled $322,000, for an average weekday peak vehicle requirement of 126.5 cars, or an average of $2,624. Vault-pulling costs, with fringes, totalled $154,000.

In 1984, the average peak vehicle requirement was 85.5 LRV's with two fareboxes each and 41 PCC cars with one each. This resulted in an average cost of $725 per farebox, or $1,450 per LRV. Together, dispatching and farebox costs totalled $4,074 per weekday peak vehicle. This was rounded off to $4,100 in the formula. It is coincidental that this was the same amount used for bus time-related maintenance costs. Because of differences in deployment strategy for on-line supervisions for bus and light rail service, light rail supervision costs were not considered part of peak vehicle costs. They were accounted for separately as described in section B.3.6.

B.3.5 Route-Mile Costs

For light rail, these include maintenance costs for fixed facilities, other than trolley wires, that would be required for the option under consideration, but would otherwise be unnecessary. For the Watertown Trolley analysis, it was assumed that A-Line service would have no impact on maintenance costs for either the Central Subway or the B-Line east of Packard's Corner. The level of maintenance currently given to the A-Line west of Packard's Corner is much lower than that required for regular revenue service. Furthermore, if A Line service is not restored, the MBTA may relocate the Watertown maintenance facility and dismantle the entire A Line. Therefore, the trolley alternatives include an estimate of full maintenance expenses for the sections of the A-Line that they would use. The A Line is currently unsignalized, like the B, C, and E lines, and is assumed to remain so. It is also assumed that the same number of signs and shelters would be required for either trolley or bus service, so costs for these are not included in any option. Fixed facility costs included in the estimates consist of maintenance expenses for track and for electric power lines.

Track

Track maintenance expenses on a given route segment can vary substantially from year to year, since the service life of most track materials is much greater than one year. Therefore, expenses from one year may be unrepresentative. Time-series data show that for MBTA rail lines as a whole, maintenance costs are fairly steady from year to year. Maintenance cost estimates for the A-Line were based on 1984 experience for surface portions of the

B, C, D and E lines, plus the Mattapan Line, and surface segments of all high-platform rapid transit lines. The following cost functions were included: Inspection of Track and Roadway, Repair and Maintenance of Track, Repair and Maintenance of Ties and Guard Timber, Preventive Maintenance, and Work Train Service. Including a distribution of fringe benefits to labor components, these expenses averaged $38,725 per two-track route-mile. With a pro-rated share of costs for supervision, tools and miscellaneous expenses, this increased to $51,000 per route-mile.

Power System

In addition to expenses for trolley wire maintenance, which are treated as mileage-variable costs, light rail service incurs maintenance expenses for cables that carry power from substations to the trolley wires. Functions included in the formula were Repair and Maintenance of Overhead D.C. Feeders and Related Switches and Repair and Maintenance of Underground D.C. Cables and Related Switches. Figures on the variation in number and type of power lines by route are not readily available. Therefore, the total 1984 system expense of $737,000 was divided by total electrified route miles for rapid transit, light rail, and trackless trolley, resulting in an average cost of $10,000 per route-mile. The combined total maintenance cost for track and power lines used in the formula was $61,000 per route-mile.

B.3.6 On-Line Supervision Costs

The cost analysis determined that for bus service, on-line supervision costs varied most directly with the number of peak vehicles per route. Most bus supervision is done either by roving inspectors in cars, or by inspectors with fixed locations at terminals serving several routes. In contrast, Green Line supervision is done primarily by inspectors who either have fixed locations or patrol a limited number of stops. Except in emergencies, the work of Green Line and bus inspectors, even at shared terminals, is independent. For A-Line alternatives, supervision costs were assumed to be determined by the number of inspector assignments required with this service but not without it. Based on present practice, there would be one full-time inspector at the outer terminal, and one at each regularly-used intermediate turnback point. None of the alternatives included sufficient short-term service to call for an inspection point other than the terminal. It was assumed that no extra inspectors would be needed east of Packard's Corner, and that patrols of present roving inspectors could be extended to A-Line points other than the terminal as needed. At 1984 wage levels, the cost of providing an inspector for all work shifts, including fringe benefits, at the A-Line outer terminal only, would be $156,000 per year.

B.3.7 Recap of Light Rail Costs

The light rail cost formula used for all A-line alternatives was as follows:

($20.59/hr.) x (Annual surface car-hours, revenue and non-revenue)

+ ($19.20/hr.) x (Annual subway car-hours, revenue and non-revenue)

+ ($1.67) x (Annual revenue and non-revenue subway miles)

+ ($2.72) x (Annual revenue and non-revenue surface miles)

+ ($62,000/year) x (No. of vehicles assigned to route, including spares)

+ ($4,100/year) x (Weekday peak vehicles scheduled on route)

+ ($61,000/year) x (Number of Route-miles needed exclusively for this service)

+ ($159,000/year) x (Number of inspector locations)

A factor of 10 percent was added to the results to account for variable costs not specifically covered in the formula.

Table B-1

WATERTOWN TROLLEY ANALYSIS
Operating Cost Estimates

Alternative	Annual Surface Trolley Operating Cost	Annual Subway Trolley Operating Cost	Annual Total Trolley Operating Cost	Annual Local Bus Operating Cost	Annual Express Bus Operating Cost	Annual Total Operating Cost	Change From Base Case	Change Excluding Subway Cost
0/1	$0	$0	$0	$2,168,471	$914,880	$3,083,351	$0	$0
2	$3,138,612	$761,821	$3,900,433	$0	$0	$3,900,433	$817,083	$55,261
3	$2,808,075	$871,151	$3,679,226	$0	$0	$3,679,226	$595,875	($275,276)
4a	$2,030,415	$776,421	$2,806,836	$283,276	$0	$3,090,112	$6,762	($769,659)
4b	$1,805,718	$687,009	$2,492,727	$283,276	$747,872	$3,523,875	$440,524	($246,485)
4b.1	$1,805,718	$687,009	$2,492,727	$283,276	$708,431	$3,484,434	$401,084	($285,925)
5	$1,453,130	$684,212	$2,137,342	$1,332,592	$914,880	$4,384,814	$1,301,463	$617,250
6	$1,171,674	$685,816	$1,857,490	$1,393,176	$914,880	$4,165,546	$1,082,195	$396,379

Note: 4b assumes Route 301 backhauls all runs via Newton Corner
4b.1 assumes some backhauls via Cambridge Street

Watertown Trolley Analysis - Table B-2
Summary of Service Units

Element	Alt 0 & Alt 1	Alt 2	Alt 3	Alt 4a	Alt 4b	Alt 4b.1	Alt 5	Alt 6
Trolley - Surface								
Annual Vehicle Hours	0	34,670	31,632	24,689	23,733	23,733	18,839	16,213
Annual Vehicle Miles	0	318,537	285,511	201,554	194,677	194,677	141,261	106,070
Total Vehicles	0	12.2	10.4	6.4	3.9	3.9	3.6	2.6
Peak Vehicles	0	10.6	9.0	5.6	3.4	3.4	3.1	2.3
Route Miles	0	5.16	4.71	3.41	3.41	3.41	2.56	1.81
Inspector Location	0	1	1	1	1	1	1	1
Trolley - Subway								
Annual Vehicle Hours	0	11,228	17,329	15,804	15,252	15,252	14,248	14,587
Annual Vehicle Miles	0	132,106	139,541	132,604	126,398	126,398	122,871	128,874
Total Vehicles	0	3.9	3.5	2.8	1.8	1.8	2.2	2.0
Peak Vehicles	0	3.4	3.0	2.4	1.6	1.6	1.9	1.7
Local Bus								
Annual Vehicle Hours	52,564	0	0	8,867	8,867	8,867	34,209	34,841
Annual Vehicle Miles	583,886	0	0	53,699	53,699	53,699	322,340	342,926
Total Vehicles	13.2	0	0	1.1	1.1	1.1	9.2	10.4
Peak Vehicles	12.0	0	0	1.0	1.0	1.0	8.0	9.0
Express Bus								
Annual Vehicle Hours	15,296	0	0	0	11,995	11,894	15,296	15,296
Annual Vehicle Miles	263,567	0	0	0	220,626	206,842	263,567	263,567
Total Vehicles	13.8	0	0	0	11.5	10.4	13.8	13.8
Peak Vehicles	12.0	0	0	0	10.0	9.0	12.0	12.0

Note: 4b assumes Route 301 backhauls all runs via Newton Corner
4b.1 assumes some backhauls via Cambridge Street

Watertown Trolley Analysis - Table B-3
Operating Costs by Service Unit

Element	Alt 0 & Alt 1	Alt 2	Alt 3	Alt 4a	Alt 4b	Alt 4b.1	Alt 5	Alt 6
Trolley - Surface								
Annual Vehicle Hours	---	$713,863	$651,296	$508,355	$488,671	$488,671	$387,898	$333,819
Annual Vehicle Miles	---	$866,421	$776,589	$548,227	$529,521	$529,521	$384,229	$288,509
Total Vehicles	---	$755,780	$641,700	$399,280	$242,420	$242,420	$221,030	$163,990
Peak Vehicles	---	$43,460	$36,900	$22,960	$13,940	$13,940	$12,710	$9,430
Route Miles	---	$314,760	$287,310	$208,010	$208,010	$208,010	$156,160	$110,410
Inspector Location	---	$159,000	$159,000	$159,000	$159,000	$159,000	$159,000	$159,000
Other Costs	---	$285,328	$255,280	$184,583	$164,156	$164,156	$132,103	$106,516
Sub-Total	---	**$3,138,612**	**$2,808,075**	**$2,030,415**	**$1,805,718**	**$1,805,718**	**$1,453,130**	**$1,171,674**
Trolley - Subway								
Annual Vehicle Hours	---	$215,587	$332,722	$303,428	$292,829	$292,829	$273,557	$280,070
Annual Vehicle Miles	---	$220,618	$233,033	$221,449	$211,085	$211,085	$205,194	$215,219
Total Vehicles	---	$242,420	$213,900	$171,120	$114,080	$114,080	$135,470	$121,210
Peak Vehicles	---	$13,940	$12,300	$9,840	$6,560	$6,560	$7,790	$6,970
Other Costs	---	$69,256	$79,196	$70,584	$62,455	$62,455	$62,201	$62,347
Sub-Total	---	**$761,821**	**$871,151**	**$776,421**	**$687,009**	**$687,009**	**$684,212**	**$685,816**
Local Bus								
Annual Vehicle Hours	$1,014,488	---	---	$171,131	$171,131	$171,131	$660,238	$672,426
Annual Vehicle Miles	$770,729	---	---	$70,883	$70,883	$70,883	$425,489	$452,663
Total Vehicles	$54,120	---	---	$4,510	$4,510	$4,510	$37,720	$42,435
Peak Vehicles	$132,000	---	---	$11,000	$11,000	$11,000	$88,000	$99,000
Other Costs	$197,134	---	---	$25,752	$25,752	$25,752	$121,145	$126,652
Sub-Total	**$2,168,471**	---	---	**$283,276**	**$283,276**	**$283,276**	**$1,332,592**	**$1,393,176**
Express Bus								
Annual Vehicle Hours	$295,221	---	---	---	$231,507	$229,562	$295,221	$295,221
Annual Vehicle Miles	$347,908	---	---	---	$291,226	$273,031	$347,908	$347,908
Total Vehicles	$56,580	---	---	---	$47,150	$42,435	$56,580	$56,580
Peak Vehicles	$132,000	---	---	---	$110,000	$99,000	$132,000	$132,000
Other Costs	$83,171	---	---	---	$67,988	$64,403	$83,171	$83,171
Sub-Total	**$914,880**	---	---	---	**$747,871**	**$708,431**	**$914,880**	**$914,880**
Grand Total	$3,083,351	$3,900,433	$3,679,226	$3,090,112	$3,523,874	$3,484,434	$4,384,814	$4,165,546

Note: 4b assumes Route 301 backhauls all runs via Newton Corner
4b.1 assumes some backhauls via Cambridge Street

APPENDIX C CAPITAL COST ESTIMATION

C.1 GENERAL INTRODUCTION AND APPROACH

The capital costs to restore the Watertown Trolley Line between Watertown and Brighton are those of rehabilitating the line and acquiring new trolleys and/or buses, for any replacement bus service. Capital costs for bus-only alternatives involve only the cost of vehicle acquisition.

There are six basic capital cost scenarios for trolleys. These include five alternative terminal locations (Watertown yard, Newton Corner, Oak Square, Brighton Center and Union Square) and various options for accompanying bus service. In addition, two bus-only alternatives were considered.

For each alternative, capital costs were calculated based on the relevant number of trolleys and buses and appropriate track, yard, wire and pole work. These costs were then divided between federal and state/local funds, and for consistency with other cost and revenue measures, were annualized using a range of discount interest rates.

C.2 MAJOR ASSUMPTIONS

- Capital costs were based on a 25 year project horizon.
- Capital costs for rolling stock are currently estimated to be $141,708 for buses and $1,060,000 for trolleys.
- The life span of the vehicles was assumed to be 12 years for buses and 25 years for trolleys.
- The ratio between Federal and state/local capital cost-sharing was assumed to be 60 percent Federal and 40 percent local. This was based on recent MBTA purchases of which half have been paid for with no Federal money and half have been paid for with 80 percent Federal funding.
- A range of discount interest rates was used in this analysis. The lower bound, 6.9 percent, is the current MBTA bond rate.[1] The midrange is 8.4 percent and the upper bound 9.9 percent.

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[1] MBTA Bond rate - 6.875 percent, as of April 1986.

- The analysis assumed that the entire purchase price of the vehicles would be allocated to the alternatives.

- All vehicle requirements incorporate a spare ratio of 1.15.

C.3 ALTERNATIVE SERVICE CONFIGURATIONS

Several trolley alternatives were analyzed. In addition to the six shown below, various options such as alternative substitute bus service, tunnels, signal pre-emption and reservations were examined. Capital costs of other options are detailed separately in the presentation of results. Alternatives 0 and 1 have identical capital costs so results are shown together.

Bus Alternatives

0. Existing Route 57 and 301 services assuming:
   - continuation of existing fare policies (Base Case).

1. Existing Route 57 and 301 services assuming:
   - a free transfer between Route 57 and the Green Line at Kenmore Station.

Trolley Alternatives

2. Watertown Square - Park Street Station assuming:
   - elimination of Routes 57 and 301.

3. Newton Corner - Park Street Station assuming:
   - elimination of Routes 57 and 301.

4a. Oak Square - Park Street Station assuming:
   - elimination of Route 57 and 301.
   - extension of Route 64 from Oak Square to Watertown Square.

4b. Oak Square - Park Street Station assuming:
   - elimination of Route 57.
   - termination of Route 301 at Oak Square.
   - extension of Route 64 from Oak Square to Watertown Square.

5. Brighton Center - Park Street Station assuming:
   - continuation of Route 301.
   - operation of Route 57 only between Watertown Square and Brighton Center.

6. Union Square - Park Street Station assuming:
   - continuation of Route 301.
   - operation of Route 57 only between Watertown Square and Union Square.

C.4 CAPITAL COSTS FOR BUS ALTERNATIVES

The only capital cost associated with the bus-only alternatives was for the vehicles (Alternatives 0, 1). The cost of a new bus is $141,708.[2] For consistency with trolley alternatives, it was assumed that the entire fleet of 28 buses (including spares) would be replaced initially. With an assumed bus life of twelve years and a project life of 25 years, there would be a total of three episodes of fleet replacement in years 0, 12 and 24.

Future bus costs[3] were calculated, assuming no change in the current fleet size, for future purchase years[4], and then the non-federal shares of these costs were discounted to present values. The total present value bus capital costs were next annualized. The capital cost calculations for this alternative are shown in Section 1 of Table C-1.

The range of interest rates used in this study reduces the possible bias of calculating annualized costs based on an inappropriate interest rate. The lower bound, 6.9 percent, is the current MBTA bond rate, as of April 1986, and reflects a non-inflationary interest rate. The mid-range is 8.4 percent and the upper bound, 9.9 percent, reflects the cost of raising capital in the private sector. See Table C-7 at the end of this appendix for intermediate results.

C.5 CAPITAL COSTS FOR TROLLEY ALTERNATIVES

Capital costs for the trolley alternatives (Alt. 2 through 6) includes trolleys, track, yard, wire and pole costs and relevant bus costs for replacement service.

A 1985 study by the MBTA Engineering Department[5] determined that certain upgrading projects would be required for restoration of revenue service on the Watertown Trolley Line. These would include reconstruction of storage and maintenance facilities and the replacement of tracks and overhead wire equipment along the Watertown-Packard's Corner portion of the line. A more detailed description of upgrading needs appears in Section C.8 .

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[2] Source: Recent MBTA purchases of RTS II buses.

[3] Uninflated costs are used in the calculation of future costs. This is appropriate as discount rates are exclusive of inflation.

[4] Only one year of the year 24 vehicle purchase were included, as the project horizon is 25 years.

[5] MBTA memorandum "Watertown Streetcar Line," Ralph L. Duvall, Chief Engineer, July 1, 1985.

Watertown Trolley Analysis - Table C-1
Present Value and Annualized Costs of Bus and Trolley Purchases

1] BUSES - Alternative 0

# Buses needed to operate line	24
Spare ratio	1.15
Total # Buses needed	28
Price per vehicle	$141,708
Total Bus Cost (Per Fleet Purchase)	$3,967,824
Local Portion @ 40%	$1,587,130

Present Value of Purchases

Bus Lifespan	12
Project Horizon	25
Purchase Episodes	3

		DISCOUNT INTEREST RATES		
		@ 6.9%	@ 8.4%	@ 9.9%
P. V. of Purchase in Year	0	$1,587,130	$1,587,130	$1,587,130
P. V. of Purchase in Year	12	$712,656	$602,922	$511,258
P. V. of Purchase in Year*	24	$26,667	$19,087	$13,724
Total Present Value		**$2,326,452**	**$2,209,138**	**$2,112,112**
Total Annualized Costs		**$197,391**	**$214,066**	**$230,900**

2] TROLLEY - Alternative 2

Trolleys

# Trolleys needed to operate line	14
Spare ratio	1.15
Total # Trolleys needed	16
Price per Trolley	$1,060,000
Total Trolley Cost	**$16,960,000**
Local Portion @ 40%	**$6,784,000**

Discount Rate	@ 6.9%	@ 8.4%	@ 9.9%
Total Annualized Costs	$575,598	$657,370	$741,641

* Only first year of year 24 purchase included in 25 year project horizon

The initial level of upgrading would influence both capital investments and annual maintenance costs in future years. For purposes of analysis, it was assumed that after initial upgrading the average annual maintenance cost for the A-line would be similar to the average for existing MBTA surface tracks, and that no significant additional capital improvements would be made during the project life. See Table C-8 at the end of this appendix for intermediate results.

C.5.1 Rolling Stock

The unit cost of a new Type-7 Trolley is $1,060,000.[6] The calculations of the vehicle costs for these alternatives were similar to the bus calculations. However, as the trolley life was assumed to be 25 years, there would be only one purchase episode in year 0. The non-federal share of the total cost was then annualized. An example calculation for Alternative 2 is shown in Section 2 of Table C-1.

C.5.2 Track and Yard

The level of upgrading assumed for costing purposes was that recommended by the 1985 MBTA analysis. As detailed in Section C.8, this level of upgrading represents the minimum necessary. It is likely that a much greater level of investment would be made before restoration of service, however. The 1985 analysis called for total reconstruction of approximately 35 percent of the line and the replacement of track joints on the remainder of the line. The above recommendations were refined in 1987[7] to reflect current pricing and to specify costs for each segment of the Watertown Trolley Line. The revised estimates provide costs for track and power work for each of the alternative endpoints of the line.

A further assumption in the CTPS analysis was that the inbound track at Newton Corner would have to be relocated along the present bus route, in order to reduce effects on traffic flow in this area. Substitute work in association with alternative end points for the line would also have to be done. Such work would include turnarounds at Newton Corner, Oak Square, Brighton Center or Union Square. The cost used for each turnaround was $250,000. This would vary somewhat according to final site-specific designs.

Yard work would include the reconstruction of Watertown Yard for Alternative 2. Alternatives 3 through 6 would not require the reconstruction of Watertown Yard, but could

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[6] Source: Current purchase price of Type-7 trolleys.

[7] MBTA Memorandum, "Watertown Line," Edward J. Rowe, Acting Chief Engineer, February 19, 1987.

require work on storage and maintenance facilities elsewhere. However, these costs should be comparable to those of reconstructing Watertown Yard. See Table C-2 for track and yard costs for each of the six trolley alternatives.

C.5.3 Wire and Pole Costs

The initial cost for upgrading the poles and overhead wires for the entire Watertown Trolley Line to the extent recommended in the MBTA analysis, would be $1,995,000. The costs for each alternative reflect the specific amount of replacement and upgrading work required for that alternative, rather than a proportional cost based on segment length. (See Table C-2).

C.6 TUNNEL, SIGNAL PRE-EMPTION AND RESERVATIONS

There are three capital cost issues within the sphere of this analysis that were handled independently of the main alternatives. These costs were for trolley priority schemes, which include a subway under Brighton Center, signal pre-emption, and reservations.

C.6.1 Tunnel

One of the alternative service strategies considered in this study was the building of a subway under Brighton Center. A minimum cost of $17.2 million was used for a half-mile tunnel under the Brighton Center business district, from east of the Winship/Washington/Cambridge intersection to west of the Washington/Foster intersection. The estimated cost of the Brighton Center tunnel was based on a similar tunnel in Pittsburgh.[8] However, labor costs in the Boston area are likely to be higher than in the Pittsburgh case. The Pittsburgh tunnel is a two-bore parallel tunnel, measuring 2,600 linear feet or approximately half a mile. The annualized non-federal cost of a tunnel at Brighton Center was estimated to be $583,744 at the 6.9 percent interest rate.

C.6.2 Signal Pre-emption

The recommended signal pre-emption system was an optical one which operates with strobe lights mounted on the top of the vehicles. The system has a range of 900 feet and drivers are required to switch on their lights on approaching a pre-empted intersection. The cost for such a signal pre-emption system is $10,000 per intersection and $1,500 per vehicle.

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[8] Source: Dormont to Mount Lebanon LRV tunnel. Engineering Department, PATransit - Pittsburgh, PA. [412] 237-7300.

Watertown Trolley Analysis - Table C-2
Initial Capital Cost of Track, Yard, Wire and Pole Work

TOTAL TRACK, YARD, WIRE AND POLE COST (Surface)

TROLLEY ALTERNATIVE	TRACK & YARD	WIRE & POLES	TURN-AROUND	TOTAL COST
2	$6,900,000	$1,995,000	$250,000	$9,145,000
3	$4,600,000	$1,785,000	$250,000	$6,635,000
4a	$2,700,000	$1,155,000	$250,000	$4,105,000
4b	$2,700,000	$1,155,000	$250,000	$4,105,000
5	$800,000	$630,000	$250,000	$1,680,000
6	$100,000	$210,000	$250,000	$560,000

ANNUALIZED NON-FEDERAL COSTS

TROLLEY ALTERNATIVE	DISCOUNT INTEREST RATES @ 6.9%	@8.4%	@9.9%
2	$310,368	$354,460	$399,900
3	$225,183	$257,173	$290,141
4a	$139,318	$159,110	$179,507
4b	$139,318	$159,110	$179,507
5	$57,017	$65,117	$73,464
6	$19,006	$21,706	$24,488

It was assumed that only intersections with relatively light cross-traffic could be pre-empted. There are eight such intersections along the entire Watertown Trolley Line west of Packard's Corner. These intersections are listed below:

- Brighton Avenue @ Linden
- Cambridge Street @ Gordon
- Cambridge Street @ Eleanor
- Cambridge Street @ Sparhawk/Warren
- Washington Street @ Foster
- Washington Street @ Brock
- Tremont Street @ Waverley
- Galen Street @ Morse/Hunt

Because the number of vehicles and pre-empted intersections varies with each alternative, specific signal pre-emption capital costs were calculated. The non-federal portion of these costs were then annualized. The results are shown in Table C-3.

C.6.3 Reservations

Trolley reservations on Brighton Avenue and Cambridge Street would allow improved travel times between Packard's Corner and Brighton Center during peak periods, by allowing increased operating speeds and reducing traffic delays. This alternative could be used alone or in conjuction with a Brighton Center tunnel. The mileage for the reservations would be as follows: Brighton Avenue 0.66 miles and Cambridge Street 0.68 or 0.52 miles with the tunnel (The tunnel under Brighton Center would reduce the required length of reservation on Cambridge street). The capital costs[9] for these reservations are detailed in Table C-4.

[9] A variety of sources were used to obtain estimates for the capital cost of reservations.

Watertown Trolley Analysis - Table C-3
Signal Pre-emption Capital Costs

Equipment and Installation Costs

Cost per Intersection = **$10,000**
Cost per Vehicle = **$1,500**

Capital Costs

ALTERNATIVE	# EQUIPPED VEHICLES	# EQUIPPED INTERSECTIONS	CAPITAL COSTS	LOCAL SHARE OF COSTS	ANNUALIZED OVER 25 YEARS @ 6.9%	@ 8.4%	@ 9.9%
0	0	0	---	---	---	---	---
1	0	0	---	---	---	---	---
2	16	8	$104,000	$41,600	$3,530	$4,031	$4,548
3	14	7	$91,000	$36,400	$3,088	$3,527	$3,979
4a	8	6	$72,000	$28,800	$2,444	$2,791	$3,148
4b	7	6	$70,500	$28,200	$2,393	$2,733	$3,083
5	6	4	$49,000	$19,600	$1,663	$1,899	$2,143
6	5	1	$17,500	$7,000	$594	$678	$765

* Including Spares

Table C-4
Capital Costs for Trolley Reservations

Reservation	Length	Track	Platforms & Crossings	Total
A] Full Length	7075	$2,353,711	$279,110	**$2,632,821**
B] Reduced Length[10] due to Tunnel under Brighton Center.	6230	$2,072,596	$275,848	**$2,348,444**

STATE/LOCAL SHARE
MARGINAL RESERVATION COST[11]

ALTERNATIVE	FULL LENGTH	REDUCED LENGTH
2	**$481,000**	**$367,000**
3	**$481,000**	**$367,000**
4a	**$481,000**	**$367,000**
4b	**$481,000**	**$367,000**
5	**$481,000**	**$367,000**
6	**$392,000**	**$392,000**

These non-federal costs are annualized under the three different interest rates being used and are presented in (Summary) Table C-5.

C.7 CAPITAL COST SUMMARIES

The capital cost summaries for all alternatives are shown in Figure C-1 on the following page, and in Table C-5 on the subsequent three pages.

Figure C-1 shows both the total present value and the annualized capital costs for all the alternatives. The capital costs for Alternative 1 were the same as Alternative 0. The results show that capital costs are dominated by vehicle acquisition costs, constituting 66 percent, 69 percent, 70 percent,72 percent, 83 percent and 93 percent in Trolley Alternatives 2, 3, 4a, 4b, 5 and 6 respectively. For the bus-only alternatives, this figure is 100 percent.

It is evident from the graph that the use of different discount interest rates has little or no effect on the present value of capital costs. Although the effect is more

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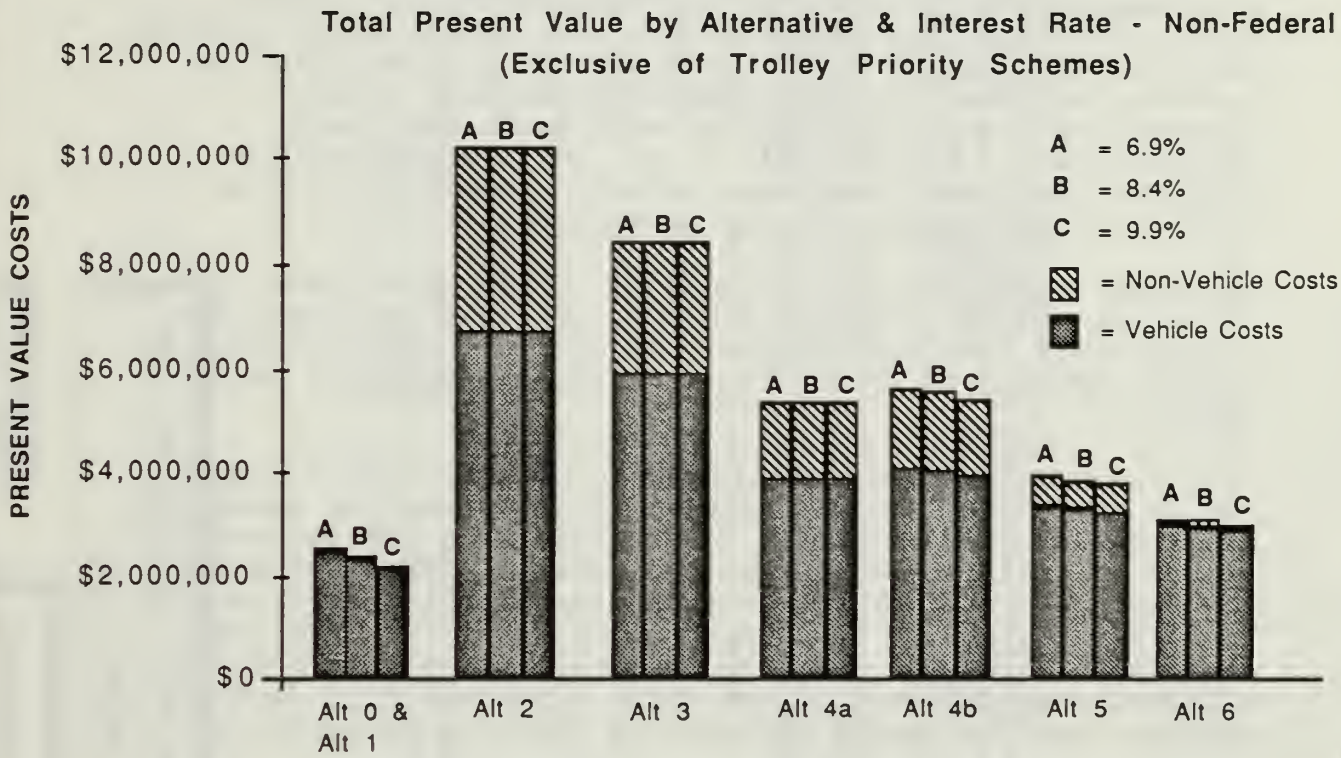
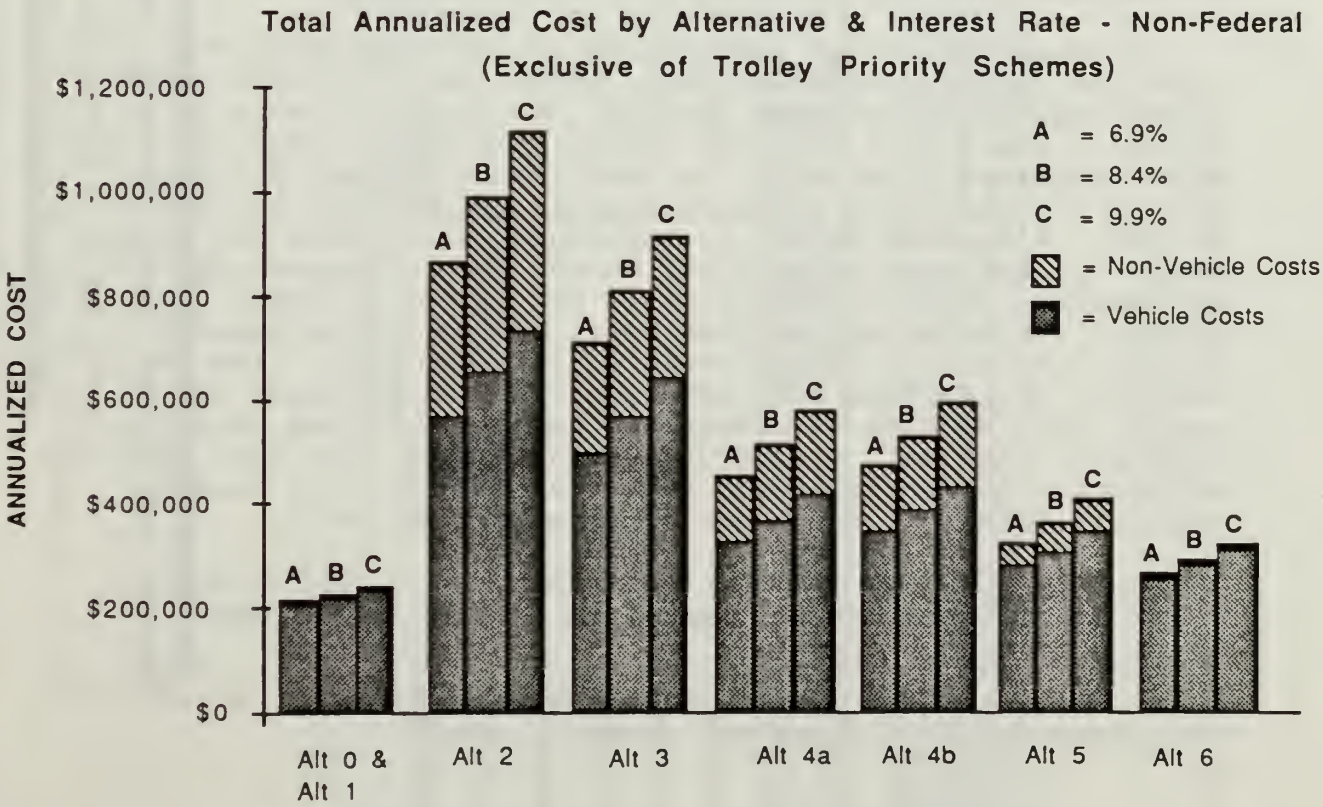
10 If a tunnel were built under Brighton Center in conjunction with the reservations, it would require a shorter reservation on Cambridge Street.

11 Excludes Track, Yard, Wire and Pole Costs, used in earlier capital cost calculations. These "Final Reservation Costs" represent the add-on cost of reservations.

WATERTOWN TROLLEY ANALYSIS - Figure C-1
Graphs of Total Present Value & Annualized Costs by Alternative & Discount Rate





noticeable when looking at annualized costs, interest rates have no effect on the ranking of the alternatives.

Annualized capital costs range from $197,400 for Alternative 0/1, to $886,000 for Alternative 2. In both present value and annualized cost terms, Alternative 2 incurs the greatest capital cost, significantly greater than the bus-only alternative. In terms of annualized costs, Alternative 2 would be $688,600 more expensive than Alternative 0. Alternatives 3, 4a, 4b, 5 and 6 would be $531,000, $273,000, $285,000, $139,000, and $72,000 more expensive than Alternative 0, respectively.[12]

Also shown in Table C-5 are the add-on annualized capital costs for trolley priority schemes. The cost of these vary considerably from approximately $4,000, for a signal pre-emption system, to around $584,000 for the Brighton Center tunnel.[13]

It could be argued that since A-line trolleys would be run in the Central Subway as part of their regular operation, a proportion of the capital costs for A-line trolley vehicles should be assigned to the Central Subway. Table C-6 shows the capital costs for all alternatives with the surface-only trolley cost, at the 6.9 percent interest rate. This does significantly reduce the total capital cost of the trolley alternatives, but only in one case, Alternative 6, does the capital cost drop below that of the bus-only alternative.

C.8 FURTHER DESCRIPTION OF A-LINE UPGRADING NEEDS

Although the A-line infrastructure has been retained since the end of revenue service, major rehabilitation would now be required to restore service. In its last years of operation the A-line received normal maintenance, but no major reconstruction except as required by highway projects. Much of the track and power system was nearly worn out even in 1969. A limited amount of subsequent track wear has been caused by equipment being moved to and from Watertown for maintenance. Most of the track is set in public roads, and has been subjected to continual wear and tear from passing vehicles, as well as the effects of sand and salt. The track and power system have both deteriorated from 18 years of weathering. Neither the track nor the power system conforms to modern Light Rail standards. Even if this line were in safe condition for immediate re-activation it would soon be necessary to shut it down again for modernization.

Estimates of the minimum work needed to rehabilitate the A-line for LRV service were prepared in 1985 by the MBTA

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[12] Percentages shown are for an 6.9 percent discount rate.
[13] Alternative 2, 6.9 percent discount rate.

WATERTOWN TROLLEY ANALYSIS

Table C-5

Present Value & Annualized Capital Costs
Surface and Subway Costs Combined, Based upon 6.9% Interest Rate

TOTAL PRESENT VALUE @ 6.9%	ALT 0 & ALT1 Bus Only	ALT 2 Trolley Watertown	ALT 3 Trolley Newton Corner	ALT 4a Trolley Oak Sq.	ALT 4b Trolley Oak Sq.+301	ALT 5 Trolley Brighton Ctr.	ALT 6 Trolley Union Square
Bus Purchases	$2,326,452			$83,088	$1,080,138	$747,788	$830,876
Trolley Purchases		$6,784,000	$5,936,000	$3,816,000	$2,968,000	$2,544,000	$2,120,000
Track & Yard Work		$2,760,000	$1,840,000	$1,080,000	$1,080,000	$320,000	$40,000
Wire & Pole Work		$798,000	$714,000	$462,000	$462,000	$252,000	$84,000
Turn-around Facilities		$100,000	$100,000	$100,000	$100,000	$100,000	$100,000
Total Capital Cost	**$2,326,452**	**$10,442,000**	**$8,590,000**	**$5,541,088**	**$5,690,138**	**$3,963,788**	**$3,174,876**
Total Annualized Capital Cost	**$197,391**	**$885,967**	**$728,831**	**$470,142**	**$482,788**	**$336,313**	**$269,377**
Annualized Marginal Costs							
Signal Pre-emption	----	$3,530	$3,088	$2,444	$2,393	$1,663	$594
Brighton Center Tunnel	----	$583,744	$583,744	$583,744	$583,744	----	----
Reservations - Full Length	----	$40,822	$40,822	$40,822	$40,822	$40,822	$33,271
Reservations - Reduced Length*	----	$31,171	$31,171	$31,171	$31,171	$31,171	$33,271

* A shorter reservation on Cambridge Street is required with a Brighton Center tunnel.

WATERTOWN TROLLEY ANALYSIS

Table C-5

Present Value & Annualized Capital Costs
Surface and Subway Costs Combined, Based upon 8.4% Interest Rate

TOTAL PRESENT VALUE @ 8.4%	ALT 0 & ALT1 Bus Only	ALT 2 Trolley Watertown	ALT 3 Trolley Newton Corner	ALT 4a Trolley Oak Sq.	ALT 4b Trolley Oak Sq.+301	ALT 5 Trolley Brighton Ctr.	ALT 6 Trolley Union Square
Bus Purchases	$2,209,138			$78,898	$1,025,671	$710,080	$788,978
Trolley Purchases		$6,784,000	$5,936,000	$3,816,000	$2,968,000	$2,544,000	$2,120,000
Track & Yard Work		$2,760,000	$1,840,000	$1,080,000	$1,080,000	$320,000	$40,000
Wire & Pole Work		$798,000	$714,000	$462,000	$462,000	$252,000	$84,000
Turn-around Facilities		$100,000	$100,000	$100,000	$100,000	$100,000	$100,000
Total Capital Cost	**$2,209,138**	**$10,442,000**	**$8,590,000**	**$5,536,898**	**$5,635,671**	**$3,926,080**	**$3,132,978**
Total Annualized Capital Cost	**$214,066**	**$1,011,831**	**$832,372**	**$536,526**	**$546,097**	**$380,437**	**$303,586**
Annualized Marginal Costs							
Signal Pre-emption	----	$4,031	$3,527	$2,791	$2,733	$1,899	$678
Brighton Center Tunnel	----	$666,672	$666,672	$666,672	$666,672	----	----
Reservations - Full Length	----	$46,621	$46,621	$46,621	$46,621	$46,621	$37,998
Reservations - Reduced Length*	----	$35,599	$35,599	$35,599	$35,599	$35,599	$37,998

* A shorter reservation on Cambridge Street is required with a Brighton Center tunnel.

WATERTOWN TROLLEY ANALYSIS

Table C-5

Present Value & Annualized Capital Costs
Surface and Subway Costs Combined, Based upon 9.9% Interest Rate

TOTAL PRESENT VALUE @ 9.9%	ALT 0 & ALT1 Bus Only	ALT 2 Trolley Watertown	ALT 3 Trolley Newton Corner	ALT 4a Trolley Oak Sq.	ALT 4b Trolley Oak Sq.+301	ALT 5 Trolley Brighton Ctr.	ALT 6 Trolley Union Square
Bus Purchases	$2,112,112			$75,433	$980,623	$678,893	$754,326
Trolley Purchases		$6,784,000	$5,936,000	$3,816,000	$2,968,000	$2,544,000	$2,120,000
Track & Yard Work		$2,760,000	$1,840,000	$1,080,000	$1,080,000	$320,000	$40,000
Wire & Pole Work		$798,000	$714,000	$462,000	$462,000	$252,000	$84,000
Turn-around Facilities		$100,000	$100,000	$100,000	$100,000	$100,000	$100,000
Total Capital Cost	**$2,112,112**	**$10,442,000**	**$8,590,000**	**$5,533,433**	**$5,590,623**	**$3,894,893**	**$3,098,326**
Total Annualized Capital Cost	**$230,900**	**$1,141,541**	**$939,076**	**$604,926**	**$611,178**	**$425,798**	**$338,715**
Annualized Marginal Costs							
Signal Pre-emption	----	$4,548	$3,979	$3,148	$3,083	$2,143	$765
Brighton Center Tunnel	----	$752,136	$752,136	$752,136	$752,136	----	----
Reservations - Full Length	----	$52,598	$52,598	$52,598	$52,598	$52,598	$42,869
Reservations - Reduced Length*	----	$40,162	$40,162	$40,162	$40,162	$40,162	$42,869

* A shorter reservation on Cambridge Street is required with a Brighton Center tunnel.

WATERTOWN TROLLEY ANALYSIS

Table C-6

Present Value & Annualized Capital Costs
Surface Costs Only, Based upon 6.9% Interest Rate

TOTAL PRESENT VALUE @ 6.9%	ALT 0 & ALT1 Bus Only	ALT 2 Trolley Watertown	ALT 3 Trolley Newton Corner	ALT 4a Trolley Oak Sq.	ALT 4b Trolley Oak Sq.+301	ALT 5 Trolley Brighton Ctr.	ALT 6 Trolley Union Square
Bus Purchases	$2,326,452			$83,088	$1,080,138	$747,788	$830,876
Trolley Purchases		$5,136,457	$4,452,000	$2,671,200	$2,018,240	$1,577,280	$1,219,000
Track & Yard Work		$2,760,000	$1,840,000	$1,080,000	$1,080,000	$320,000	$40,000
Wire & Pole Work		$798,000	$714,000	$462,000	$462,000	$252,000	$84,000
Turn-around Facilities		$100,000	$100,000	$100,000	$100,000	$100,000	$100,000
Total Capital Cost	**$2,326,452**	**$8,794,457**	**$7,106,000**	**$4,396,288**	**$4,740,378**	**$2,997,068**	**$2,273,876**
Total Annualized Capital Cost	**$197,391**	**$746,179**	**$602,919**	**$373,009**	**$402,204**	**$254,291**	**$192,930**
Annualized Marginal Costs							
Signal Pre-emption	----	$3,530	$3,088	$2,444	$2,393	$1,663	$594
Brighton Center Tunnel	----	$583,744	$583,744	$583,744	$583,744	----	----
Reservations - Full Length	----	$39,464	$39,464	$39,464	$39,464	$39,464	$32,592
Reservations - Reduced Length*	----	$29,813	$29,813	$29,813	$29,813	$29,813	$32,592

* A shorter reservation on Cambridge Street is required with a Brighton Center tunnel.

Engineering Department, and updated in February 1987. An additional, more qualitative inspection was made by CTPS in March 1987. The conclusion was that the level of upgrading identified by the MBTA Engineering Department would be essential to re-opening the A-line, and that even greater rehabilitation would be desirable if a decision were made to re-activate the line. The major findings are discussed below, by component.

C.8.1 TRACK

Rails

The entire A-line has girder-rail, which incorporates a flangeway on one side of the rail head. It is imbedded in pavement, with only the flangeway and running surface exposed. The present MBTA standard for girder-rail is 149 lbs per yard. Most A-line rail was 100 lbs per yard or lighter when new. New 149 lb rail, being less flexible, would hold alignment and surface much better than the present rail. When new, the present rail would have had a head depth of over one inch. Between Brighton and Watertown the railhead depth, checked by CTPS at numerous locations, was found to be only about one half inch. This would be insufficient to resist the stresses imparted by modern light rail vehicles operating every few minutes. Similar measurements east of Brighton Center were not possible. Available information indicates that the rail there is not as old, but it also shows significant surface wear.

Most rail joints on the A-line are welded, but more than ten percent are bolted. These cannot be kept tightened without removing pavement, so the interval between bolt-tightenings has been much greater than it would be on exposed rails. Once bolts become loose, the end of one rail can raise higher than the other, exposing it to pounding by passing vehicles. The CTPS inspection found numerous such track joints severely damaged in this manner, with short sections of railhead entirely missing in some cases. The worst damage was at intersections, where vehicles strike the rails from several different angles. Some damaged rail joints have been repaired by setting in short sections of new rail, but this increases the number of joints exposed to damage.

Ties

The rails are supported by wooden ties buried under the pavement. During the CTPS inspection it was not possible to check the ties, but tests made by the MBTA Engineering Department in 1985 indicated that on at least one third of the line tie replacement was needed. Wherever rails are to be replaced, all ties should also be replaced since they are at least halfway through their expected service life. It is

less expensive to replace ties on a clear roadbed than underneath rails.

C.8.2 Power Distribution

Poles

Like the rest of the Green Line, the A-line was powered from overhead trolley wire. From Packard's Corner to Union Square, the wire is suspended from cross-arms on a single pole line in the median barrier. On the rest of the route the trolley wires are supported by span wires strung between curbside poles on both sides of the street. All poles are iron or steel and are used exclusively for MBTA wires except that from the Brighton-Newton border almost to Newton Corner the south ends of the span wires are anchored to wooden utility poles also used by telephone and Edison Company wires.

Most of the metal poles are quite old, possibly dating from the original electrification of the A-line before 1900. Most have not been painted in several years and are heavily coated in rust scale. Without scraping the poles, it is difficult to determine the extent of the rust damage, but some appear to be significantly weakened at the base. Throughout most of the route, poles lean noticeably. This is apparently the result of gradual settling, and wires have generally been adjusted to compensate. The 1985 MBTA Engineering report on the A-line recommended replacement of approximately ten percent of the poles. This estimate appears to be very conservative. Poles not replaced should be scraped, and painted, and in many cases re-set. The cost estimates do not include this work.

Wires

Cars used on the A-line in the past used trolley poles for current collection. Boeing LRV's and Type-7 cars both use pantographs. This requires a heavier gauge trolley wire than is now in place on the A-line. The present wires are suspended over the centerlines of each track, but for pantograph operation wires must be set to sweep back and forth across moving pantographs to provide uniform wear. Pantographs require a total side-to-side clearance of about 40 inches, which is not provided by much of the present A-line wire suspension. Revenue service on the A-line would require virtually total replacement of present trolley wires and suspension system.

The MBTA cost estimates were based on total replacement of the trolley wire using a suspension system similar to that now used on other Green Line surface branches. Because of problems with that suspension system, however, the MBTA is planning conversion to another system. The new system is

much heavier than the present one, and would require almost 100 percent pole replacement if adopted on the A-line. The cost estimates do not include this work.

Power Supply

Trolley wires can carry 600 volt D.C. power only for relatively short distances. Power is fed into the wires along the line from parallel heavy-duty cables. On the A-line, the power supply lines are carried in underground conduits, except that between the Brighton-Newton border and Hibbard Road they are carried on the north-side trolley-wire support poles. At present, the distance between feed wires from the supply lines to the trolley wires on the A-line is generally 400 feet or more, with inbound and outbound wires fed from the same supply lines. This would be inadequate for the power demands of LRV's or Type 7's. On sections of the Green Line where the power system has been upgraded recently, feeder lines are spaced at approximately 100 feet, with independent supplies to inbound and outbound tracks. The A-line power system would require less extensive upgrading, since single-unit cars would be run, at relatively low speeds, but for both reliability and energy conservation, there should be some upgrading.

In the past, sub-stations at Oak Square and Watertown converted power for the A-line from 12,000 volts A.C., at which it was generated, to 600 volts D.C. used in the trolley wires. An undetermined amount of sub-station modernization, possibly including installation of sub-stations at one or more new locations, would be needed for future A-line service. The MBTA cost estimates do not include sub-station work.

The condition of power distribution cables in underground conduit sections was not determined by CTPS. In the section with above-ground cables, although the cables themselves appear sound, insulation is mostly frayed or entirely missing. This is potentially an extreme hazard to anyone working around the cables and should be corrected. At present, the A-line power system is energized only when cars are to be moved over it, usually at night. With revenue service, the wires would be energized most of the time, so the chance of anyone coming into contact with live cables would be much greater. The MBTA cost estimates do not include costs for power cable replacement.

C.8.3 Oak Square Loop

In Alternatives 4a and 4b, A-line trolley service would terminate at Oak Square. In Alternatives 2 and 3, service would continue west of Oak Square, but retention of a loop at Oak Square for short turnbacks would be desirable. The existing Oak Square loop has a total length of about 860 feet

of which about 520 feet is in heavily-travelled public ways, and about 340 feet on private land. The loop has a single track, except that there is a second track long enough for two LRV's on the private land. The rail on all of the loop is extremely worn. Within the private way section it is of very antiquated design. As on the rest of the line, trolley wires are unsuitable for pantograph service.

Any alternative including use of the Oak Square loop would require total reconstruction of this facility. This work was included in the estimates for Alternatives 4a and 4b. Since Alternatives 2 and 3 could be operated without an Oak Square loop, the capital costs for those alternatives did not include work there. Because of the extra flexibility provided by an Oak Square loop, it is likely that it would be upgraded for Alternatives 2 and 3, at an additional cost of $250,000.

C.8.4 Watertown Yard

The original Watertown carhouse and yard were built in 1901. The carhouse itself was rebuilt in the early 1970's, but most of the track and wire outside of the carhouse was not upgraded. Some of it may be original installation. At present, yard tracks are used for storing equipment awaiting maintenance. These cars move relatively infrequently, and if derailments occur they are of minor consequence. For revenue service, cars would be running continually over the yard tracks, and any derailments would result in significant disruption to operations. The MBTA Engineering report calls for complete reconstruction of the Watertown Yard tracks and power system for any service alternative requiring the use of this facility. This is appropriate, but some additional design work is needed to determine the number and location of tracks needed to accomodate both revenue-service trolleys and other vehicles that would be kept at Watertown. Yard capacity is currently less than in 1969 because of the removal of some tracks to make room for bus and trackless trolley parking.

Table C-7

WATERTOWN TROLLEY ANALYSIS
Bus Capital Costs - Intermediate Results - Summary Tables

1] FLEET SIZE

ALTERNATIVE	# Buses Rt. 301	# Buses Rt. 57	Substitute Bus	BASIC FLEET SIZE	TOTAL* FLEET SIZE
0	12	12	0	24	28
1	12	12	0	24	28
2	- -	- -	- -	- -	- -
3	- -	- -	- -	- -	- -
4a	0	0	1	1	1
4b	10	0	1	11	13
5	0	0	8	8	9
6	0	0	9	9	10

* Including Spares (15 percent)

2] PRESENT VALUE OF THREE PURCHASES

ALTERNATIVE	TOTAL PRESENT VALUE DISCOUNT INTEREST RATES 6.90%	8.40%	9.90%
0	$2,326,452	$2,209,138	$2,112,112
1	$2,326,452	$2,209,138	$2,112,112
2	- - -	- - -	- - -
3	- - -	- - -	- - -
4a	$83,088	$78,898	$75,433
4b	$1,080,138	$1,025,671	$980,623
5	$747,788	$710,080	$678,893
6	$830,876	$788,978	$754,326

3] ANNUALIZED COST

ALTERNATIVE	TOTAL ANNUALIZED COST DISCOUNT INTEREST RATES 6.90%	8.40%	9.90%
0	$197,391	$214,066	$230,900
1	$197,391	$214,066	$230,900
2	---	---	---
3	---	---	---
4a	$7,050	$7,645	$8,246
4b	$91,646	$99,388	$107,204
5	$63,447	$68,807	$74,218
6	$70,497	$76,452	$82,464

Table C-8

WATERTOWN TROLLEY ANALYSIS
Trolley Capital Costs - Intermediate Results - Summary Tables

1] TRACK, YARD, WIRE & POLE COSTS AND FLEET SIZE

ALTERNATIVE	TRACK / YARD WORK	WIRES & POLES	TOTAL* FLEET SIZE
0	- -	- -	- -
1	- -	- -	- -
2	$6,900,000	$1,995,000	16
3	$4,600,000	$1,785,000	14
4a	$2,700,000	$1,155,000	9
4b	$2,700,000	$1,155,000	7
5	$800,000	$630,000	6
6	$100,000	$210,000	5

* Including Spares (15 percent)

2] STATE/LOCAL SHARE OF TROLLEY PURCHASES

ALTERNATIVE	TOTAL PRESENT VALUE
0	- - -
1	- - -
2	$10,342,000
3	$8,490,000
4a	$5,358,000
4b	$4,510,000
5	$3,116,000
6	$2,244,000

3] ANNUALIZED COST

	TOTAL ANNUALIZED COST DISCOUNT INTEREST RATES		
ALTERNATIVE	6.90%	8.40%	9.90%
0	---	---	---
1	---	---	---
2	$877,482	$1,002,141	$1,130,609
3	$720,347	$822,682	$928,144
4a	$454,607	$519,191	$585,747
4b	$382,658	$437,019	$493,042
5	$264,382	$301,941	$340,647
6	$190,395	$217,444	$245,319

APPENDIX D REVENUE ESTIMATION

D.1 INTRODUCTION

Restoring A-line trolley service and eliminating Routes 57 and 301 would affect MBTA passenger revenue due to a change in MBTA patronage and to the different trolley and bus fare structures.

In this appendix, the methods used in and the results obtained from estimating annual revenue for each service alternative are presented.

D.2 GENERAL APPROACH

The general approach involved deriving or assuming a fare- mix for each service component of each alternative, computing an average passenger fare from each fare-mix and applying these average fares to estimates of annual patronage in order to obtain annual revenue. Patronage was expanded from daily weekday figures to annual figures so that the revenue could be computed on an annual basis. (Refer to Appendix A for the derivation of weekday patronage estimates.)

The fare-mixes used were based on survey data from Routes 57 and 301. For the bus alternatives, they were used directly; for the trolley alternatives, they were used in various combinations, consistent with the assumption that most trolley patrons would be former bus patrons.

D.3 ANALYSIS ASSUMPTIONS

The following major assumptions underlie the estimation of passenger revenue.

- The fare structure for a restored Watertown trolley would be the same as it now is for the other Green Line branches.

- The current bus fare structure will remain.

- Bus/Green Line transfer policy will continue as is. (Alternative 1, for analysis purposes, specifies a free transfer at Kenmore Station.)

- The majority of patrons of a restored trolley service would be drawn from MBTA bus Routes 57 and 301 and therefore exhibit similar fare type characteristics.

Additionally, for trolley alternatives, revenue transference from other services to the A-line was not accounted for. To the extent to which this transference occurred, net MBTA revenue resulting from trolley restoration would be less than that indicated for the trolley alternatives alone.

D.4 METHOD AND RESULTS

D.4.1 Bus Alternative

Revenue for the bus alternatives consists of that obtained on Routes 57 and 301 and on the Green Line by Route 57 transferees. The latter are termed "surface-to-subway" travellers in this alternative.

The patronage on MBTA bus Route 57, Watertown to Kenmore Station, was obtained from ridechecks performed by CTPS for the Central North Corridor Bus Study in the Fall of 1984. Patronage on MBTA express bus Route 301, Brighton Center to Downtown Boston, was obtained from ridechecks conducted by CTPS in the Spring of 1986.

The estimated number of people who transfer between Route 57 and the Green Line at Kenmore Station was obtained from a January 1985 on-board questionnaire. These transferees comprise 27 percent of all Route 57 riders.

The fare mix (including pass-mix) of Route 57 patrons was also obtained from the January 1985 on-board survey. It was assumed that this fare mix has remained constant, but even if small changes have occurred in it since 1985, there would only be a negligible change in the revenue estimates. The fare mix of Route 301 patrons was obtained from an on-board survey administered by CTPS in the Spring of 1986 as part of the West Bus Corridor Study. It is assumed that this fare mix has also remained stable through the design year (1987). Table D-1 shows fare-mixes and average fares.

To derive an average fare for monthly pass users, the pass-mix information from the bus surveys was combined with pass use information from the 1985 fare-mix survey, the most recent from which information was available.[1] This pass use information showed that, systemwide, passes were used on the rapid transit system (including the subway portion of the Green Line) 36 times per month. Passes were used on buses and the surface Green Line 47 times per month. Throughout the analysis, these figures alone and in combination were applied to monthly pass costs to derive average fares per

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[1] CTPS Technical Report #57, 1985 MBTA Fare-Mix Sampling Program: Analysis and Documentation, January 1987.

Watertown Trolley Analysis - Table D-1
Fare Mixes and Average Fares

Route 57

FARE CATEGORY	FARE MIX	AVERAGE ONE-WAY FARE
Adult Cash	50.5%	$0.50
Adult Pass	39.4%	$0.38
Senior Citizen	3.7%	$0.10
Handicapped	0.2%	$0.10
Child Cash	1.5%	$0.25
Student Pass	4.7%	$0.23
TOTAL	100.0%	**$0.42**

Route 301

FARE CATEGORY	FARE MIX	AVERAGE ONE-WAY FARE
Adult Cash	30.0%	$1.00
Adult Pass	66.0%	$0.77
Senior Citizen	2.0%	$0.50
Handicapped	0.0%	$0.50
Child Cash	1.0%	$0.50
Student Pass	1.0%	$0.23
TOTAL	100.0%	**$0.83**

Watertown Trolley Analysis - Table D-1
Fare Mixes and Average Fares

Route 57 to Green Line

FARE CATEGORY	FARE MIX	AVERAGE ONE-WAY FARE
Adult Cash	50.5%	$1.10
Adult Pass	39.4%	$0.90
Senior Citizen	3.7%	$0.20
Handicapped	0.2%	$0.20
Child Cash	1.5%	$0.55
Student Pass	4.7%	$0.23
TOTAL	100.0%	**$0.94**

Surface A-line, Ex-Rte. 57 Market, surface only
(Excludes transferees from substitute buses)

FARE CATEGORY	FARE MIX	AVERAGE ONE-WAY FARE*
Adult Cash	50.5%	$0.43
Adult Pass	39.4%	$0.38
Senior Citizen	3.7%	$0.06
Handicapped	0.2%	$0.06
Child Cash	1.5%	$0.20
Student Pass	4.7%	$0.23
TOTAL	100.0%	$0.38

* Outbound fares are weighted average of free fares (west of Kenmore) and fares paid outbound at Kenmore.

Watertown Trolley Analysis - Table D-1
Fare Mixes and Average Fares

Surface A-line, Ex-Rte. 57 Market, surface to subway
(Excludes transferees from substitute buses)

FARE CATEGORY	FARE MIX	AVERAGE ONE-WAY FARE
Adult Cash	50.5%	$0.68
Adult Pass	39.4%	$0.51
Senior Citizen	3.7%	$0.10
Handicapped	0.2%	$0.10
Child Cash	1.5%	$0.33
Student Pass	4.7%	$0.23
TOTAL	100.0%	$0.56

Surface A-line, Ex-Rte. 301 Market, surface to subway
(Excludes transferees from substitute buses)

FARE CATEGORY	FARE MIX	AVERAGE ONE-WAY FARE
Adult Cash	30.0%	$0.68
Adult Pass	66.0%	$0.53
Senior Citizen	2.0%	$0.10
Handicapped	0.0%	$0.10
Child Cash	1.0%	$0.33
Student Pass	1.0%	$0.23
TOTAL	100.0%	$0.56

Watertown Trolley Analysis - Table D-1
Fare Mixes and Average Fares

Substitute Bus, Ex-Rte. 57 Market, Bus Only

FARE CATEGORY	FARE MIX	AVERAGE ONE-WAY FARE
Adult Cash	50.5%	$0.50
Adult Pass	39.4%	$0.38
Senior Citizen	3.7%	$0.10
Handicapped	0.2%	$0.10
Child Cash	1.5%	$0.25
Student Pass	4.7%	$0.23
TOTAL	100.0%	$0.42

Substitute Bus, Ex-Rte. 57 Market, Bus to A-line Surface

FARE CATEGORY	FARE MIX	AVERAGE ONE-WAY FARE
Adult Cash	50.5%	$0.93
Adult Pass	39.4%	$0.76
Senior Citizen	3.7%	$0.16
Handicapped	0.2%	$0.16
Child Cash	1.5%	$0.45
Student Pass	4.7%	$0.23
TOTAL	100.0%	$0.79

Watertown Trolley Analysis - Table D-1
Fare Mixes and Average Fares

Substitute Bus, Ex-Rte. 57 Market, Bus to A-line Subway

FARE CATEGORY	FARE MIX	AVERAGE ONE-WAY FARE
Adult Cash	50.5%	$1.18
Adult Pass	39.4%	$0.87
Senior Citizen	3.7%	$0.20
Handicapped	0.2%	$0.20
Child Cash	1.5%	$0.58
Student Pass	4.7%	$0.23
TOTAL	100.0%	$0.97

Substitute Bus, Ex-Rte. 301 Market, Bus to A-line Subway

FARE CATEGORY	FARE MIX	AVERAGE ONE-WAY FARE
Adult Cash	30.0%	$1.18
Adult Pass	66.0%	$0.87
Senior Citizen	2.0%	$0.20
Handicapped	0.0%	$0.20
Child Cash	1.0%	$0.58
Student Pass	1.0%	$0.23
TOTAL	100.0%	$0.94

Watertown Trolley Analysis - Table D-1
Fare Mixes and Average Fares

Subway-only

FARE CATEGORY	FARE MIX	AVERAGE ONE-WAY FARE
Adult Cash	51.3%	$0.60
Adult Pass	35.2%	$0.53
Senior Citizen	10.0%	$0.10
Handicapped	1.0%	$0.10
Child Cash	2.5%	$0.30
Student Pass	0.0%	$0.23
TOTAL	100.0%	**$0.51**

pass use or per unlinked trip, as well as to derive revenue per linked trip.[2]

For Route 57, pass-mix information was not available for sub-groups of travellers, so assumptions were made about the pass mix of surface-only and surface-to-subway travellers. It was assumed that the former use the "A" pass (surface only) exclusively. Route 57 surface-to-subway pass users were assumed to use the "C" through "F" passes in the proportions indicated by the survey information.

Pass users on Route 301 overwhelmingly use "C" passes (rapid transit, streetcar, local and express bus). For simplicity, it was assumed that all pass users on this route use "C" passes and that none of them transfer to or from rapid transit at the downtown ends of their trips.

Weekday boardings were converted to annual boardings using conversion factors. These factors account for weekend, holiday and lower summer ridership. The following was assumed in their derivation: 199 non-summer weekdays, 54 Saturdays and Saturday-like holidays, 59 Sunday and Sunday-like holidays, and 53 summer weekdays per year. Saturday and Sunday ridership for each alternative was estimated using empirical relationships between weekday and weekend ridership on the corridor buses. Summer weekday ridership was assumed to be 4.2 percent less than that for non-summer weekdays, based on generalized system-wide relationships.

Table D-2 shows the estimated annual revenue for the two bus alternatives obtained by applying the average fares to the annual patronage estimates. As shown, the current bus services, including Green Line revenue obtained from Route 57 transferees, generate just over $2.0 million per year. Revenue obtained from Alternative 1, which includes a free bus-to-Green Line transfer at Kenmore Station, would decline to approximately $1.8 million, notwithstanding its higher patronage.

D.4.2 Trolley Alternatives

Two major assumptions underlie the estimation of revenue for trolley alternatives. First is that the A-line would be priced consistent with other Green Line branches. Second, since the major share of A-line patrons would be former Route

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[2] A linked trip is defined as a complete trip from initial origin to ultimate destination, irrespective of the number of mode transfers. An unlinked trip, for purposes of this analysis, is a surface or surface-to-subway trip on a single vehicle, or a subway trip, irrespective of the number of underground transfers made between subway lines.

Watertown Trolley Analysis - Table D-2
Annual Revenue Generation
Alternative 0: Base Case - Maintain Existing Routes 57 and 301

	Weekday Boardings	Weekday to Annual Factor	Annual Boardings	Average One-Way Fare	**Annual Revenue**
Route 57					
Surface Only	7,203	290.5	2,092,472	$0.42	**$878,838**
Surface to Subway	2,664	290.5	773,892	$0.94	**$727,458**
Total/Average	9,867	290.5	2,866,364	$0.56	**$1,606,297**
Route 301					
Surface Only	2,221	249.9	555,028	$0.83	**$460,673**
TOTAL	**12,088**	**283.0**	**3,421,391**	**$0.60**	**$2,066,970**

Watertown Trolley Analysis - Table D-2
Annual Revenue Generation
Alternative 1: Existing Bus Service with Free Transfer Between Route 57 and Green Line

	Weekday Boardings	Weekday to Annual Factor	Annual Boardings	Average One-Way Fare	**Annual Revenue**
Route 57					
Surface Only	7,203	290.5	2,092,472	$0.42	**$878,838**
Surface to Subway	3,136	290.5	911,008	$0.47	**$428,174**
Total/Average	10,339	290.5	3,003,480	$0.44	**$1,307,012**
Route 301					
Surface Only	2,221	249.9	555,028	$0.83	**$460,673**
TOTAL	**12,560**	**283.3**	**3,558,507**	**$0.50**	**$1,767,685**

Watertown Trolley Analysis - Table D-2
Annual Revenue Generation
Alternative 2: Watertown Square - Park Street; Eliminate Routes 57 and 301

	Weekday Boardings	Weekday to Annual Factor	Annual Boardings	Average One-Way Fare	**Annual Revenue**
A Line					
Route 57 Market					
Surface to Surface	7,466	280.5	2,094,213	$0.38	$795,801
Surface to Subway	3,298	280.5	925,089	$0.56	$518,050
Total/Average	10,764	280.5	3,019,302	$0.44	$1,313,851
Route 301 Market					
Surface to Subway	2,358	280.5	661,419	$0.56	$370,395
Total/Average	13,122	280.5	3,680,721	$0.46	$1,684,245
Substitute Bus					
Route 57 Market	0	NA	0	NA	0
Route 301 Market	0	NA	0	NA	0
Total/Average	0	NA	0	NA	0
Route 301 (if retained)					
Total/Average	0	249.9	0	$0.83	$0
Subway Increase					
Total/Average	1,253	290.5	363,997	$0.51	$185,638
TOTAL	**14,375**	**281.4**	**4,044,718**	**$0.46**	**$1,869,884**

Watertown Trolley Analysis - Table D-2
Annual Revenue Generation
Alternative 3: Newton Corner - Park Street; Eliminate Routes 57 and 301

	Weekday Boardings	Weekday to Annual Factor	Annual Boardings	Average One-Way Fare	**Annual Revenue**
A Line					
Route 57 Market					
Surface Only	6,510	280.5	1,826,055	$0.38	**$693,901**
Surface to Subway	2,876	280.5	806,718	$0.56	**$451,762**
Total/Average	9,386	280.5	2,632,773	$0.44	**$1,145,663**
Route 301 Market					
Surface to Subway	2,314	280.5	649,077	$0.56	**$363,483**
Total/Average	11,700	280.5	3,281,850	$0.46	**$1,509,146**
Substitute Bus					
Route 57 Market	0	NA	0	NA	**0**
Route 301 Market	0	NA	0	NA	**0**
Total/Average	0	NA	0	NA	**0**
Route 301 (if retained)					
Total/Average	0	249.9	0	$0.83	**$0**
Subway Increase					
Total/Average	1,183	290.5	343,662	$0.51	**$175,267**
TOTAL	**12,883**	**281.4**	**3,625,512**	**$0.46**	**$1,684,413**

Watertown Trolley Analysis - Table D-2
Annual Revenue Generation
Alternative 4a: Oak Square - Park Street; Eliminate Routes 57 and 301

	Weekday Boardings	Weekday to Annual Factor	Annual Boardings	Average One-Way Fare	Annual Revenue
A Line					
Route 57 Market					
Surface Only	5,646	280.5	1,583,703	$0.38	$601,807
Surface to Subway	2,045	280.5	573,623	$0.56	$321,229
Total/Average	7,691	280.5	2,157,326	$0.43	$923,036
Route 301 Market					
Surface to Subway	1,879	280.5	527,060	$0.56	$295,153
Total/Average	9,570	280.5	2,684,385	$0.45	$1,218,189
Substitute Bus					
Route 57 Market	1,166	266.7	310,972	$0.42	$130,608
Route 301 Market	57	266.7	15,202	$0.38	$5,777
Total/Average	1,223	266.7	326,174	$0.42	$136,385
Route 301 (if retained)					
Total/Average	0	249.9	0	$0.83	$0
Subway Increase					
Total/Average	1,117	290.5	324,489	$0.51	$165,489
TOTAL	**11,910**	**280.0**	**3,335,048**	**$0.46**	**$1,520,063**

Watertown Trolley Analysis - Table D-2
Annual Revenue Generation
Alternative 4b: Oak Square - Park Street; Eliminate Route 57; Operate Rt 301 to Oak Square Only

	Weekday Boardings	Weekday to Annual Factor	Annual Boardings	Average One-Way Fare	**Annual Revenue**
A Line					
Route 57 Market					
Surface Only	5,416	290.5	1,573,348	$0.38	**$597,872**
Surface to Subway	1,943	290.5	564,442	$0.56	**$316,087**
Total/Average	7,359	290.5	2,137,790	$0.43	**$913,959**
Route 301 Market					
Surface to Subway	658	290.5	191,149	$0.56	**$107,043**
Total/Average	8,017	290.5	2,328,939	$0.44	**$1,021,003**
Substitute Bus					
Route 57 Market	1,166	266.7	310,972	$0.42	**$130,608**
Route 301 Market	0	266.7	0	$0.38	**$0**
Total/Average	1,166	266.7	310,972	$0.42	**$130,608**
Route 301 (if retained)					
Total/Average	1,488	249.9	371,851	$0.83	**$308,636**
Subway Increase					
Total/Average	1,044	290.5	303,282	$0.51	**$154,674**
TOTAL	**11,715**	**283.0**	**3,315,044**	**$0.49**	**$1,614,922**

Watertown Trolley Analysis - Table D-2
Annual Revenue Generation
Alternative 5: Brighton Center - Park Street; Eliminate Route 57, Retain Route 301

	Weekday Boardings	Weekday to Annual Factor	Annual Boardings	Average One-Way Fare	**Annual Revenue**
A Line					
Route 57 Market					
Surface Only	4,546	290.5	1,320,613	$0.38	**$501,833**
Surface to Subway	1,368	290.5	397,404	$0.56	**$222,546**
Total/Average	5,914	290.5	1,718,017	$0.42	**$724,379**
Route 301 Market					
Surface to Subway	0	290.5	0	$0.56	**$0**
Total/Average	5,914	290.5	1,718,017	$0.42	**$724,379**
Substitute Bus					
Route 57 Market	2,398	290.5	696,619	$0.42	**$292,580**
Route 301 Market	0	290.5	0	$0.38	**$0**
Total/Average	2,398	290.5	696,619	$0.42	**$292,580**
Route 301 (if retained)					
Total/Average	2,221	249.9	555,028	$0.83	**$460,673**
Subway Increase					
Total/Average	1,020	290.5	296,310	$0.51	**$151,118**
TOTAL	**11,553**	**282.7**	**3,265,974**	**$0.50**	**$1,628,750**

Watertown Trolley Analysis - Table D-2
Annual Revenue Generation
Alternative 6: Union Square - Park Street; Eliminate Route 57, Retain Route 301

	Weekday Boardings	Weekday to Annual Factor	Annual Boardings	Average One-Way Fare	Annual Revenue
A Line					
Route 57 Market					
Surface Only	3,408	290.5	990,024	$0.38	**$376,209**
Surface to Subway	662	290.5	192,311	$0.56	**$107,694**
Total/Average	4,070	290.5	1,182,335	$0.41	**$483,903**
Route 301 Market					
Surface to Subway	0	290.5	0	$0.56	**$0**
Total/Average	4,070	290.5	1,182,335	$0.41	**$483,903**
Substitute Bus					
Route 57 Market	4,031	290.5	1,171,006	$0.42	**$491,822**
Route 301 Market	0	290.5	0	$0.38	**$0**
Total/Average	4,031	290.5	1,171,006	$0.42	**$491,822**
Route 301 (if retained)					
Total/Average	2,221	249.9	555,028	$0.83	**$460,673**
Subway Increase					
Total/Average	1,038	290.5	301,539	$0.51	**$153,785**
TOTAL	**11,360**	**282.6**	**3,209,907**	**$0.50**	**$1,590,184**

57 and 301 riders, it was assumed that the A-line fare-mix would be the same or similar to the bus fare-mixes.

The revenue estimate for each trolley alternative consists of that obtained on the A-line from surface travellers, on the A-line from subway-only travellers, from substitute bus users and from Route 301 users, if that route is retained.[3] One accounting convention should be noted at the outset. Revenue from the first market, A-line surface travellers, excludes that obtained from substitute bus-to-trolley transferees; such revenue is accounted for in the substitute bus market revenue estimate.

D.4.2.a Define Travel Submarkets

The revenue estimation method entailed first disaggregating two of the four basic groups of travellers cited above into finer groups defined by their specific travel behavior, hence total trip fares. There are three such sub-markets of travellers contained in the A-line surface ridership estimates. The first would be composed of ex-Route 57 riders travelling solely on the surface portion of the line. A second group would be composed of ex-Route 57 riders travelling into the subway on the A-line and the third would be ex-Route 301 riders travelling into the subway on the A-line.

To be precise, each of these three groups would include newly induced A-line surface travellers, in addition to the actual ex-bus riders. These induced travellers were assumed to be similar to the ex-bus riders - indeed, their numbers were estimated by applying elasticities to the bus riders - and to thus exhibit the same fare-mixes as them.[4]

The first subgroup of A-line surface travellers, ex-Route 57 riders travelling solely on the surface, was disaggregated further into two sub-subgroups based on assumed outbound boarding location. It was assumed that 20 percent of Route 57 patrons who now board outbound at Kenmore Station would, after switching to the A-line, walk further west to Blanford

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[3] Surface A-line travellers are defined as those who have at least one trip-end on the surface portion of the line. Subway-only travellers, as their label implies, are defined as those who travel solely on the subway portion of the A-line.

[4] Such things as eliminating a transfer at Kenmore Station and lower average fares would "induce" new riders who do not currently ride Routes 57 or 301. (See Appendix A)

Street and board outbound for free.[5] Most, however, would continue to board outbound at Kenmore and pay a fare because of their having a trip end within or east of Kenmore Square and due to it being a 0.3 mile walk to Blanford Street. Sixteen percent of total outbound travellers on the line, after accounting for this phenomenon, would board at Kenmore Station and pay a fare, and the other 84 percent would board at all other stops and pay nothing.

Substitute bus riders were disaggregated into four separate submarkets. The first is made up of ex-Route 57 riders who would use only the bus and not transfer to the A-line. The second is composed of those who would transfer to the A-line and use it on the surface only. The third is those who would transfer to the A-line and ride it into the subway, and the fourth is ex-Route 301 riders who would transfer to the A-line and ride it into the subway. Again, the reason for disaggregating travellers in this fashion is that each group would have a different average fare.

The market of new central subway riders induced by the presence of the A-line was not subdivided, nor was the fourth and final major market - Route 301 riders for the alternatives in which the route is retained.

D.4.2.b <u>Assign Fare Mixes to Each Travel Submarket</u>

The underlying fare mix assumed for each submarket was based on the Route 57 and 301 fare mixes. Ex-Route 57 and 301 riders of the A-line were assumed to have the same fare mixes as they do now on the buses.

Rather than assuming a fare-mix for induced subway-only riders, the actual rapid transit fare mix found from the 1985 fare-mix study was used. This fare mix would not necessarily be equivalent to that of the Central Subway Green Line, but it would be close, and it was deemed the best information available.

Substitute bus users were assumed to have the same fare-mixes as they now do on Routes 57 and 301. Route 301 riders, for the alternatives in which it is retained, were assumed to continue to exhibit the same fare-mix as now. (See Table D-1).

D.4.2.c <u>Calculate Average Fares</u>

Once fare-mixes were assigned to each travel submarket, average fares were calculated. As in the bus alternatives,

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[5] A shift of 20 percent would result in a boarding pattern consistent with other Green Line branches. Passengers on the latter were counted by CTPS in 1985.

imputing a fare to pass trips required making some assumptions about travel behavior.

Surface A-line pass users would be dominated by "A", "B" (rapid transit and streetcar), and "C" pass users. Those travelling solely on the surface portion of the line were assumed to use "A" passes exclusively. Those travelling into the subway were assumed to use a combination of "B" and "C" passes exclusively, the implicit assumption being that the "B" pass users do not travel on buses.

Substitute bus pass users would use "A" and "C" passes. Those using only the bus and not the A-line were assumed to use "A" passes. Those transferring to the A-line and alighting on the surface were assumed to use "A" passes, as well. Those transferring to the A-line and travelling into the subway were assumed to use "C" passes.

Subway-only pass users were assumed to use "B" and "C" passes.

Throughout the analysis, when pass users in a particular travel submarket were assumed to use only one or two pass types, "D" through "F" passes were sometimes ignored. This was done to simplify the analysis, and because these passes represent such a small percentage of the underlying bus pass mixes, the consequences of this simplification were not deemed to be serious.

It should be noted that, due to a lack of information on subway line transferrence, no pass or cash revenue from the subway portion of trips was separated and allocated to lines other than the A-line. Therefore, revenue attributable specifically to the services under consideration is overstated to some unknown extent. For the trolley alternatives, the pool of revenue subject to allocation to other rapid transit lines declines, as a portion of total revenue, as the line becomes shorter. This means that actual revenue from the longer alternatives might not exceed that from the shorter alternatives by as much as it now appears to. In any event, the base case bus alternative would retain its position as the highest revenue producer, a position that will become apparent below.

D.4.2.d <u>Annual Revenue Calculation</u>

The average trip fares calculated above were applied to estimates of annual boardings, for each travel market or submarket, to obtain annual revenue. Weekday boardings were converted to annual boardings using factors similar to those used for the bus alternatives. The factors vary by submarket depending on the assumed relationship between weekday and weekend levels-of-service and patronage. (See Table D-2)

Annual revenue for trolley alternatives would vary from $1.87 to $1.52 million. Alternative 2, Watertown to Park Street, would result in the highest revenue of the trolley service alternatives and Alternative 4a, Oak Square to Park Street with no Route 301, the least. In all cases, trolley revenue would be less than that obtained from the base case bus alternative.

D.5 SUMMARY OF FINDINGS - ALL ALTERNATIVES

D.5.1 General Findings

Table D-3 and Figure D-1 show revenue for all bus and trolley alternatives, divided by travel market.

- Annual passenger revenue, at $2.07 million, would be highest for the base case bus alternative even though two of the trolley alternatives would have higher ridership. It would exceed that from trolley alternatives by 10 to 36 percent or by $197,000 to $547,000, depending on the alternative.

- The base case bus alternative would have the highest revenue largely because MBTA fare policy dictates that the average fare would be lower on the A-line than it is on the buses currently.

- Trolley annual passenger revenue would range from a high of $1.87 million for the Watertown alternative to a low of $1.52 million for the Oak Square without Route 301 alternative.

- For trolley alternatives 2 through 4b, most of the revenue would result from the A-line surface. For alternatives 5 and 6, less than half the revenue would be from the surface A-line, as substitute bus and Route 301 revenue would become more significant. Subway revenue represents 9 to 11 percent of all trolley alternative revenue.

D.5.2 Alternative-Specific Findings

D.5.2.a Bus Alternatives

Alternative 0: Annual revenue generated currently is $1.6 million on Route 57 (and the Green Line from transferees) and $461,000 on Route 301, for a total of $2.07 million.

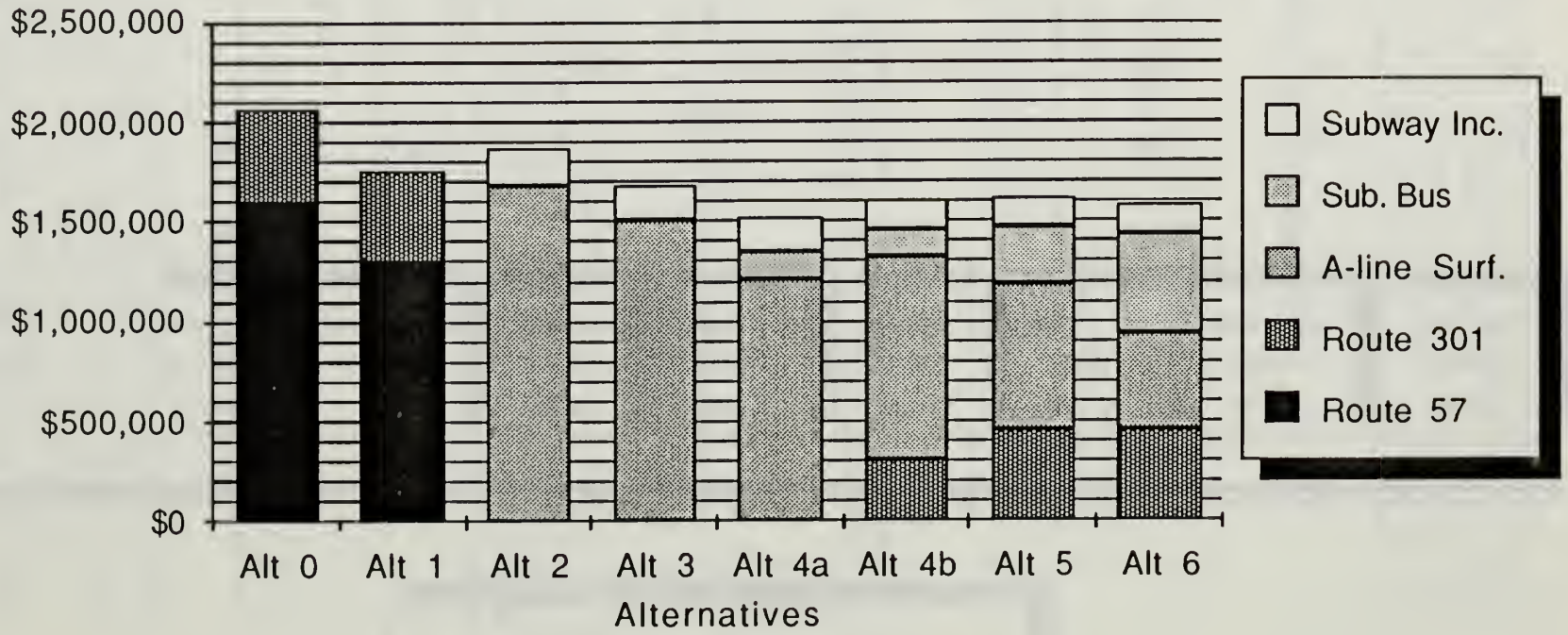
Alternative 1: With this alternative, 3136 of 10,339 riders would utilize the free transfer at Kenmore, generating $428,000 in revenue on the paid portion of the trip. Route 57 riders not transferring would generate $879,000 in revenue. Route 301 riders, as in Alternative 0, would generate $461,000 in fare revenue. Total revenue for the alternative would be $1.77 million.

Table D-3

WATERTOWN TROLLEY ANALYSIS
Annual Revenue by Alternative ($000's)

REVENUE SOURCE	ALT 0 Bus Only Base Case	ALT 1 Bus Only free Transfer	ALT 2 Trolley Watertown	ALT 3 Trolley Newton Cor.	ALT 4a Trolley Oak Sq.	ALT 4b Trolley Oak Sq.+301	ALT 5 Trolley Bright. Cent.	ALT 6 Trolley Union Sq.
Route 57	1,606	1,307	-	-	-	-	-	-
Route 301	461	461	-	-	-	309	461	461
A-line	-	-	1,684	1,509	1,218	1,021	724	484
Substitute Bus	-	-	-	-	136	131	293	492
Subway Increase	-	-	186	175	165	155	151	154
Total	**2,067**	**1,768**	**1,870**	**1,684**	**1,520**	**1,615**	**1,629**	**1,590**
% Below ALT 0	-	**14.5%**	**9.5%**	**18.5%**	**26.5%**	**21.9%**	**21.2%**	**23.1%**

WATERTOWN TROLLEY ANALYSIS, FIGURE D-1
Annual Passenger Revenue, by Alternative



The free transfer would attract an additional 472 trips, generating $58,000 in new revenue. However, the free transfer given to existing riders would amount to a loss of $357,000 in existing revenue, for a net loss of $299,000.

D.5.2.b Trolley Alternatives

Alternative 2: Revenue for this alternative would total $1.9 million, or $197,100 (9.5 percent) lower than the base case. This would occur in spite of an 18 percent increase in overall ridership, and would be due to the lower average fare that would be charged on the A-line, based upon current MBTA fare policies.

Alternative 3: Revenue would total $1.68 million ($1.5 million surface A-line, $175,000 subway increase), or 18.5 percent lower than the base case. As in the previous alternative, lower fare revenue would be entirely attributable to the difference in fare structures between Green Line service and bus service, and would occur in spite of a 6.6 percent increase in passenger trips.

Alternative 4a: With this alternative, ridership would decrease 1.5 percent, and revenue would decrease 26.5 percent to $1.52 million ($1.21 million A-line surface, $136,400 substitute bus, and $165,500 subway increase). The revenue decrease would be due to the difference in fare structures, and to a decrease in the number of trips made into the subway from west of Oak Square. (The decrease in trips would result from relocation of the transfer point to Oak Square where the transfer time would be significantly increased.)

Alternative 4b: For this alternative, due to the continuation of Route 301 to Oak Square, revenue would be slightly higher than for Alternative 4a, even though ridership would be slightly lower. This would be due to the number of riders who would continue to ride Route 301 in spite of the higher fare. Total revenue for the alternative would be $1.61 million ($1.0 million A-line surface, $130,600 substitute bus, $308,600 Route 301, and $154,700 subway increase), or 21.9 percent lower than current revenues. As with all other trolley alternatives, most of the revenue loss would be due to differences between Green Line and local bus fares and to a reduced number of trips from west of Oak Square.

Alternative 5: Revenue for this alternative would be higher than for Alternatives 4a and 4b in spite of lower ridership. This would occur due to the relatively short length of the A-line, which would require a significant number of riders to transfer at Brighton Center. The accompanying transfer charge and the higher round trip fare for trips into the subway (75 cents in, 60 cents out, versus 60 cents both ways

for transfers to the subway at Kenmore) would offset much of the loss caused by the lower round trip surface fare. Revenue for this alternative would be $724,400 on the surface A-line, $292,600 on the substitute bus service, $460,700 on Route 301, and $151,100 from the subway increase, for a total of $1.63 million, 21.2 percent lower than the base case.

Alternative 6: With this alternative, the surface A-line would also be short enough so that a large percentage of riders would have to take the substitute bus to get to it. As a result, these riders would continue to pay two fares, therefore reducing the revenue loss caused by the difference in mode fare structures. However, the transfer point at Union Square would be more inconvenient than at Brighton Center and would force more riders to transfer. This would reduce overall ridership and, hence, total revenue to $1.59 million.

APPENDIX E GREEN LINE IMPACT ESTIMATION

E.1 COORDINATION OF A-LINE OPERATION WITH OTHER GREEN LINE BRANCHES

E.1.1 Description of Shared Segments

In all options for restoring trolley service on all or part of the Watertown line, cars from that line would operate over the tracks of the existing B-line east of the intersection of Commonwealth Avenue and Brighton Avenue, at Packard's Corner. The B-line enters the Central Subway at a portal at Blandford Street, 0.95 miles east of Packard's Corner and 0.24 miles west of Kenmore Station, the first stop in the subway, where it joins the C and D lines.

Present track layout requires that cars entering the subway from the B-line continue at least as far as Park Street station before turning back. Crossovers in the subway west of Park Street are suitable for emergency use only, and the B-line does not connect directly with the Kenmore loop. Cars can also continue beyond Park Street to Government Center, North Station, or Lechmere. East of Copley Junction in the subway, the E-line also uses the same tracks as the B, C, and D lines.

E.1.2 Selection of Inner Terminal

Overall ridership in the Central Subway is much heavier west of Park Street than between Park Street and Lechmere. Consequently, some routes have always terminated short of Lechmere. At most times, 80 to 85 percent of passengers entering the Central Subway from points on the surface lines travel no further than Park Street. None of the present four routes differs significantly from this average. Therefore, assignment of turnback points has always been based more on operating considerations than on demand.

In the past, when the A-line was operated, its terminal was apparently always Park Street. For purposes of analysis, it has been assumed that restored A-line service would again terminate at Park Street. However, this might have to be changed if service did not run through to Watertown. To maintain reliable service, it is necessary for schedules to include slack time at least at one end of a route, and for vehicles to be able to wait at the terminal from actual arrival time until the next scheduled departure time. Cars turning back at Park Street can be held only until the arrival of the next train on the loop track before they start blocking traffic. Consequently, cars terminating at Park Street are scheduled to turn back immediately upon arrival, with all schedule correction being made at the outer terminal.

Watertown Yard, and to a lesser extent Oak Square, both have off-street layover capacity. Service terminating at Newton Corner would use a proposed multi-modal transportation center, which could include a layover track. The specific configuration of a turnback at Brighton Center has not been determined, but it would likely be on a public street, where cars could not be left standing. A Union Square terminal would most likely also be in the street, but a reservation in this area could include some layover capacity.

The Government Center loop, like the Park Street loop, lacks layover capacity. Therefore, A-line service operating from a western terminal without layover capacity would have to go to either North Station or Lechmere. The proposed new North Station design would include layover capacity greater than or equal to that at the present North Station. One of the existing routes could be cut back to Park Street if an extension of the A-line north of Park Street would result in too much service on that segment.

E.1.3 B-Line Surface Capacity

The B-line is unsignalized west of the Blandford Street subway portal. Spacing of trains is limited only by a requirement that each operator maintain a safe stopping distance behind the preceding train. This theoretically allows headways as short as 15 seconds. As discussed in section E.1.4, however, once cars reach the subway the minimum headway is about 30 seconds, and this must include C, D, and E as well as A and B-line cars. Therefore, theoretical track capacity between Packard's Corner and Blandford Street is not the limiting factor for service on that segment.

From a less theorectical standpoint, the combined average headway of A and B-line service between Packard's Corner and the subway portal under the maximum service A-line option would be over two minutes. More frequent service than that has been operated on this segment at times in the past. From a track capacity standpoint, there do not appear to have been significant problems operating both the A-line and the B-line on the shared track before 1969, so there would not likely be in the future. Increasing the number of vehicles using any facility inevitably increases the potential for interference, however.

One constraint on operation of both the A and B lines at present is the much higher power consumption rates of LRV's and Type 7's compared to the PCC cars used before discontinuance of the A-line. It is often necessary to re-space cars on the line in order to avoid overloading the power system. Planned improvements to the power system should, however, eliminate this problem within a few years.

E.1.4 Central Subway Capacity

The Central Subway is equipped throughout with automatic block signals, which control the spacing of cars. Distance between signals varies, with the longest blocks imposing a spacing of about 30 seconds between trains. There have been no significant changes in the signal system since the discontinuance of A Line service in 1969. The overall theoretical capacity limit imposed by the signal system is one train every 30 seconds, or 120 trains per hour. During peak periods, dwell times of trains at stations can be a more important factor than signal spacing in determining capacity, however. For traffic to keep flowing, the average time spent by trains at each station including allowances for acceleration and deceleration must be less than the average time between train arrivals. Past experience, and theoretical calculations, both indicate that in peak hours the Central Subway operates with satisfactory travel times only up to a maximum of about 70 trains per hour past a given point. The controlling segment is between Copley Junction and Boylston Station, where trains of the B, C, D, and E lines, and the A-line, if operated, all share a two-track line. At present, in the morning peak hour there are 42 scheduled trains through this section, plus up to 15 extra trains run on an as-needed basis. With full restoration of Arborway service, there would be about 50 scheduled trains per hour, but fewer extras. Full service on the A-line would contribute about 10 more trains per hour, for a total of 60, plus extras. Planned frequency improvements on the existing routes would further reduce the amount of excess capacity.

In 1984, because of a coupler problem, it was necessary to run all of the LRV's on the Green Line as single cars. This resulted in a doubling of frequency on the B, C, and D lines, and a total of 71 peak hour trips between Copley Junction and Park Street. This did, in fact, result in significant deterioration in service, because of congestion.

A study of the Central Subway currently in progress will provide more definite information on capacity constraints and methods of dealing with them. Operation of three-car trains is under consideration, but feasibility of this is still uncertain.

As on the surface, headways in the subway are currently restricted by the inadequate power system. Again, however, improvements planned or underway should eliminate this as an obstacle to A-line service restoration.

E.1.5 Conclusion

Restoration of A-line service would result in lower average frequencies on the shared portion of the B-line and in the Central Subway than have been operated in the past. The Central Subway is the more critical of the two segments. There, A-line service in addition to existing and shared service would result in overall peak frequencies approaching the theoretical and

observed practical limit. For the immediate future, an inadequate power supply limits the possibilities for additional subway service.

In the long run, it appears that the Central Subway could accommodate A-line service. The closer traffic levels are to capacity, however, the greater the chances are of individual cars experiencing delays. As further detailed in section E.3, addition of A-line service in the subway would result in relatively little net reduction in peak-hour loads on trains on other routes. Therefore, reductions in station dwell times would not compensate for the fact that each station and each signal block in the subway would have to serve more trains per hour than at present.

E.2 IMPACT OF A-LINE SERVICE ON B-LINE SURFACE RIDERSHIP

E.2.1 General

Restoration of A-line service could draw riders from the B-line in two areas. These are the segment from Blandford Street to Packard's Corner, where the two routes would share the same track, and from Packard's Corner to Washington Street, where some current B-line riders are also within walking distance of the A-line. For purposes of cost and revenue analysis of the A-line, such diversions were not explicitly considered, because they would have no net impact on MBTA revenue. The level of service assumed on the A-line for costing purposes would provide little or no capacity for such diversions during peak hours when passengers have the most incentive to seek alternatives to the B-line. Adding this capacity to the A-line would increase both operating cost and capital cost, since more cars would be needed. Because the A-line is longer than the B-line and would have slower average running speeds, it would be less costly to remedy congestion on the B-line by increasing service directly on that line than by running more A-line service.

E.2.2 Potential Diversions Packard's Corner to Blandford Street

The shared section of the A and B-lines includes seven stops: Babcock Street, Pleasant Street, St. Paul Street, B.U. West, B.U. Central, B.U. East, and Blandford Street. Six of these have relatively low use for morning inbound peak boardings. Only Babcock Street accounts for over 100 boardings between 7:00 and 9:00 a.m. With the level of service assumed in Alternative 2, which would have the most A-line cars, A-line service would account for about 40% of the trains on this segment. With random passenger arrivals, it would be expected that about 40% of boardings would divert to Watertown cars given sufficient capacity. This would amount to a total of 110 peak-hour riders, or an average reduction of five passengers per car on the B-line, and an addition of 11 passenger per car on the A-line. About eight of these per car would pass through the peak load point at B.U. Central. Given assumed A-line demand from other points, however, this would result in A-line cars being more crowded than B-line cars are now. This would reduce the incentive for diversions.

The Packard's Corner stop on the B-line is just west of the junction with the A-line, on Commonwealth Avenue. A-line cars would serve Packard's Corner from a separate stop on Brighton Avenue. This would force passengers boarding inbound trains at Packard's Corner either to guess in advance which train would arrive first, or to stand between the two stops and make a decision when a train came into view. This would probably result in less B-line-to-A-line diversions here than at stops further east. At a 40% diversion rate, about 95 peak hour passengers would shift at Packard's Corner, or nearly as many as at all stops further east combined. Again, such diversions would be subject to availability of capacity on A-line cars.

E.2.3 West of Packard's Corner

Between Packard's Corner and the end of the B-line, the walking distance between the two lines is never over one mile. It appears unlikely that there is significant potential for diversion between the two lines further west than Washington Street, where the two routes are 0.6 miles apart. Beyond that point, most passengers would perceive a much further walk to one route than to the other. In addition, several hills form a natural dividing line between the routes.

Based on actual street layout, five B-line stops west of Packard's Corner appear susceptible to diversion of riders to the A-line. These are Fordham Road, Harvard Avenue, Allston Street, Warren Avenue, and Washington Street. Boarding counts for these stops do not show specific origins of passengers. Based on land use, and on general observations at the stops, ridership appears to be more or less equally divided between the north and south sides of the B-line. Given equal fares and similar levels of service, it would be expected that the only current B-line riders who would divert to the A-line are those whose walking distance would be less to the latter than to the former. Such passengers would be those who now choose the longer walking distance to the B-line over taking Route 57 in order to gain the lower surface-subway fare and to avoid the Kenmore transfer.

As a general rule, the proportion of walk-in passengers using surface transit services declines sharply with distance. About 85% of walk-in can be expected to come from within one quarter mile, and over 90% from within one third of a mile. If similar figures apply to the B-line, the number of present north-side walk-ins starting from points closer to the A-line would range from about half at Fordham Road and Harvard Avenue down to under 10% at Washington Street. This would result in a diversion of about 180 additional peak-hour surface-subway riders from the B-line to the A-line under the most frequent service alternative on the A-line given adequate capacity on A-line vehicles. Harvard Avenue alone would account for 85 of these.

With the present fare differential between the B-line and the Route 57 bus, and the avoidance of transfer using the B-line,

it is likely that the average walk-in distance to the B-line is somewhat greater than assumed above. Therefore, the number of potential diversions would be understated. The greatest likelihood of higher diversions would be at Harvard Avenue, where the two routes are within sight of each other. On the other hand, some surface-to-surface passengers with origins closer to the B-line than to Route 57 now use Route 57 because of its lower surface-only fare. There are an estimated 50 of these riders in the peak hour. With restored A-line service, these passengers would be diverted back to the B-line.

Adjusting both for above-average B-line walk distances and A to B-line diversions, it still appears unlikely that A-line service would result in a net decrease of more than 300 peak-hour B-line boardings west of Packard's Corner.

E.2.4 Operating Cost Implications of Ridership Diversions from B-line to A-line

It has been suggested in public meetings that A-line service would draw sufficient ridership away from the B-line to allow a reduction in B-line service, and a related operating cost saving that should be deducted from A-line expenses. The analysis above indicates a maximum potential diversion of about 500 peak-hour riders from the B-line to the A-line at the proposed headway, if there were adequate capacity on the A-line cars. Of these, about 470 would be on B-line trains at the peak load point. With present schedules, this is an average of 39 passengers per train, or 19.5 per car. This would reduce the average peak-hour peak-load per car from 96 to 77. To maintain present average loads on B-line trains, 2.5 trains could be dropped in the peak hour. However, since the A-line analysis does not provide capacity for these diversions, at least three more peak-hour A-line trips would need to be added to accommodate the diversions. Since this would alter the relative frequencies of A-line and B-line service east of Packard's Corner, there would be some additional diversions on that section.

The level of service used in the A-line cost calculations would not accommodate B-line diversions, so it would be inappropriate to deduct B-line cost savings from these A-line costs. Because of the relative operational characteristics of the A and B lines, any net cost reduction attained by reducing B-line through service and increasing A-line service could also be attained by reducing B-line through service but adding more B-line short-turns. Therefore, although possibilities exist for shifting both riders and costs between the A and B lines, the operating cost calculation procedure used does not overlook any real potential savings for which A-line service would be a requirement.

In off-peak hours, the levels of service assumed for the A-line would provide some excess capacity for B-line diversions. At such times, however, the average number of diversions per

train would be too limited to call for a service cutback on the B-line.

E.3 IMPACT OF A-LINE SERVICE ON CENTRAL SUBWAY OPERATING COSTS

Within the Central Subway, operation of A-line cars would mean that passengers who now transfer from Route 57 buses to the B, C, and D lines at Kenmore would no longer do so. This would leave more capacity on these cars for other subway passengers. Counts taken at Kenmore indicate that at most 235 passengers transfer from Route 57 buses in the a.m. peak. Of these, about 200 pass through the peak-load point. This is about the same as the capacity of 1.5 LRV's. Distributed among 67 currently scheduled peak-hour cars, it is equivalent to about three passengers per car.

Most of the passengers on A-line cars would be people who do not currently travel through the Central Subway. At the level of service used in the analysis, A-line cars at the peak load point in the subway would provide extra capacity for subway riders equivalent to less than one carload per hour. This could potentially draw an additional two passengers per car from existing service. The overall average reduction at the peak-load points would be five passengers per car, or about 5 percent. This is so small that passengers on most trains would perceive little or no change in loadings.

In conclusion, little or no reduction of existing service, and hence little reduction of cost, would likely take place to offset operating costs of A-line cars within the subway. Since most of the benefits of A-line subway service would go to passengers from the surface A-line corridor, it is appropriate to allocate most of the expense of A-line car subway operation to the A-line corridor.

APPENDIX F TRAFFIC IMPACT ANALYSIS

F.1 INTRODUCTION

The analysis described in this appendix addresses three traffic-related concerns associated with replacing buses with trolleys. First, is the impact on traffic on Allston/Brighton streets, including the effect of trolley priority schemes. Then, the potential beneficial impact of removing Route 301 buses from downtown Boston streets is discussed. Finally, the impact of restoring trolley service through Newton Corner is discussed.

F.2 GENERAL APPROACH

The general approach used was to collect current traffic-related data, to represent and evaluage current traffic conditions and then to apply traffic engineering procedures to forecast conditions under the trolley scenarios. Based upon data available within the scope of the analysis, rigorous quantification of traffic impacts was, in some cases, impossible. However, much of the potential impact of trolleys can reasonably be framed in qualitative terms such as safety and physical logistics.

F.3 METHOD AND RESULTS

F.3.1 Allston/Brighton

This section of the traffic analysis was highly detailed. Two issues were addressed: the net impact on traffic of substituting trolleys for buses, and further impacts that would result from trolley priority schemes.

F.3.1.a Substitution of Trolleys for Buses

To determine traffic related impacts in Allston/Brighton, the approach taken was to analyze, in very specific terms, the impacts on one intersection that is deemed to represent something between a typical and worst-case intersection, and to use those results to make a general statement about trolley impacts along the Allston/Brighton portion of the alignment.

In Allston/Brighton, arterial traffic signals are relatively close, so that the signalized intersections control the capacity of the road. A trolley or bus stopped

within 250 feet of an intersection will have an effect on the intersection's capacity, and, therefore, more of an impact on traffic than if stopped elsewhere. For this reason, intersection capacity, and the effects of transit vehicles on it, are the focus here.

The intersection chosen for analysis is Washington Street at Chestnut Hill Avenue and Market Street, in Brighton Center. It is typical of most signalized intersections along the Route 57/trolley alignment because it is a relatively simple four legged intersection. It is, however, among the more heavily travelled intersections along the alignment, so any degradation in the level-of-service there due to trolley operation would be worse than the average degradation that a typical auto driver would face elsewhere along the alignment. The intersection, being in Brighton Center, is in an area of concern to Brighton Center merchants.

The analysis was done for the PM peak hour because this period has the highest traffic volumes of the day. In Brighton Center, the peak hour is from 4:45 to 5:45 PM.

Field data on the intersection's geometry, signalization and traffic volumes were collected on Thursday, February 12, 1987. Various measures of the intersection's performance were then computed from these data and then recomputed, assuming substitution of trolleys for buses.

Existing Conditions With Buses

Three measures of the way the intersection now works were calculated: the volume-to-capacity ratio (V/C ratio), the average stopped delay per vehicle (ASD/V), and the latter measure's associated level of service (LOS), ranging from A to F.[1] The impact that trolleys would have on these measures is the basis of the Allston/Brighton analysis.

The V/C ratio indicates how well an intersection performs with regard to the traffic volume using it compared to the maximum volume that theoretically can use it. The ASD/V measures, in seconds, how long a vehicle is typically stopped at the intersection. The associated LOS measure implies a general description of how well the intersection works with regard to delays and the relative numbers of vehicles that are compelled to stop. LOS A indicates free-flowing traffic, while LOS F indicates severe congestion.

Several characteristics control the capacity of an intersection. Geometric conditions of importance include the

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[1] Refer to the Highway Capacity Manual, Transportation Research Board, 1985, for a complete explanation of terms and method presented in this appendix.

number and width of lanes, grades, the existence of exclusive left or right turn lanes, and parking conditions. Traffic conditions include the number of heavy vehicles (including transit vehicles), the number of transit vehicles that stop to serve passengers, and pedestrian flow rates. Lastly, the type of signalization and its timing and phasing is a crucial contributor to an intersection's level of service.

A two-stage analytic process was followed in order to gauge the impacts of Route 57 and 301 buses on the intersection. First, the passenger car equivalent (PCE) of each bus stopping at the intersection to serve passengers was calculated. Then, the total PCE's for all of the peak hour buses stopping at the intersection were added to the non-transit vehicular volumes going through the intersection. The resulting V/C ratios, ASD/V and LOS measures show how the intersection performs now with bus traffic.

The bus stops that have the greatest impact on the intersection's capacity are the near-side stops: Washington at Waldo westbound and Washington between Baldwin and Argus eastbound. Far-side stops, having far less impact, are not considered in this analysis. Also, the impact of Route 63 buses traversing the intersection on the northbound and southbound legs is included and held constant through the analysis.

In estimating the PCE of buses, several steps were required. Table F-1 shows how the bus PCE's were calculated. The number of buses actually stopping at the intersection in the peak hour was derived from ridecheck data. Also known from ridechecks is the number of passengers who board and alight at the two stops of interest. Furthermore, field observations confirmed how many of the stopping buses pull over to the curb lane and how many stop in the through traffic lanes. Intersection geometrics and the Washington Street green/cycle ratio (g/C) were derived from field inspection.

The negative impact that buses have on the intersection is a function of the number of them that stop to serve passengers, the average amount of time that they are stopped, and where they stop. In the PM peak hour, Route 301 buses do not stop at either of the two near-side stops of interest, so only Route 57 buses have a real impact on the east and west approaches of the intersection during that time.

The average stopped time per bus or dwell time, for buses stopping in the through lanes, was calculated by combining passenger service time and dead time. Passenger service time is the sum of that required for boardings and that required for alightings. It was assumed that service time per boarding is 3.0 seconds and that service time per alighting is 0.9 seconds. Dead time, the time when the vehicle is

stopped before and after passengers are served, was assumed to be 5.0 seconds per vehicle. All of these values are based on a combination of Boston-based and nationally-based research.[2] Dwell time per bus, then, was calculated as follows:

D = (Service Time/Boarding x Boardings) + (Service Time/ Alighting x Alightings) + Dead Time

This dwell time was only applied in cases where buses stop in a through lane of traffic. Based on field observations, about half of the buses were assumed to stop completely or partially in the through lanes. The effect that these buses have on traffic is a function of their dwell time plus loss time (L). The latter refers to the additional impact of a transit vehicle on a traffic stream due to that traffic having to decelerate, accelerate and queue when a transit vehicle stops. This value was assumed to be 6.0 seconds, based on national data.

The effect that buses that stop in the curb lane have on vehicular traffic is, of course, less than the effect of those stopping in through traffic lanes. Dwell time is not an issue in this case, but the time required for the bus to decelerate out of and accelerate back into the through lane imposes a delay on other vehicles. For the roughly half of the buses that pull into the curb lane, it was assumed that the delay they impart on other vehicles is 4.0 seconds per bus.

Table F-1 shows that the average dwell time per Route 57 bus in the PM peak hour is 13.4 seconds outbound and 12.8 seconds inbound. The table shows how dwell time, the measures described above, and the intersection's characteristics were used to calculate the PCE per bus.

The saturation flow rate of Washington Street approaches was calculated previously, assuming no bus traffic. This measure is defined as the maximum rate of vehicle flow that can pass through the intersection from one approach in an hour, given its traffic and geometric characteristics and assuming that the approach has 100% of real time available as effective green time. The real capacity of the Washington Street approaches is then a product of the saturation flow rate and the real amount of green time available per cycle (g/C).

Stopped buses, in effect, rob traffic of a certain amount of this hourly capacity. The amount of capacity loss is

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[2] See Chapter 12 of the Highway Capacity Manual and Chapter 7 of Transportation and Traffic Engineering Handbook, Institute of Transportation Engineers, 1982.

Watertown Trolley Analysis, Table F-1
Passenger Car Equivalents of Buses - PM peak Hour
Washington @ Market/Chestnut Hill

INPUTS:	
Stopped buses/ peak hour (4:45-5:45)	9
If pullout, time loss/bus (secs)	4.0
Service time/ boarding (secs)	3.0
Service time/ alighting (sec)	0.9
Dead time/ vehicle (secs)	5.0
If no pullout, loss time (L)	6.0
green/Cycle (g/C)	0.38
Adj or through lane cap @100% g (s)	1125
INTERMEDIATE CALCULATIONS:	
If no pullout, ave. dwell time - OB (D)	13.4
If no pullout, ave. dwell time - IB (D)	12.8
CALCULATION OF PCE's:	
OUTBOUND:	
IF BUSES STOP IN CURB LANE:	
# buses/pk. hr./dir. (n)	5
time loss/hr (secs) @4*n	20
green time/hr avail. (secs)	1368
% loss in lane capacity	1.5%
adj. lane capacity @ 100% g	1125
adj. lane capacity/hr of green	427.5
capacity loss in pcph	6.3
PCE	1.3
IF BUSES STOP IN THROUGH LANE:	
# buses/pk. hr./dir.	4
time loss/hr (secs) @(g/C)*n*(D+L)	29
green time/hr avail. (secs)	1368
% loss in lane capacity	2.2%
adj. lane capacity @ 100% g	1125
adj. lane capacity/hr of green	427.5
capacity loss in pcph	9.2
PCE	2.3
Average PCE's on OB (westbound) approach	1.7
INBOUND:	
IF BUSES STOP IN CURB LANE:	
# buses/pk. hr./dir.	5
time loss/hr (secs) @4*n	20
green time/hr avail. (secs)	1368
% loss in lane capacity	1.5%
adj. lane capacity @ 100% g	1125
adj. lane capacity/hr of green	427.5
capacity loss in pcph	6.3
PCE	1.3
IF BUSES STOP IN THROUGH LANE:	
# buses/pk. hr./dir.	4
time loss/hr (secs) @(g/C)*n*(D+L)	29
green time/hr avail. (secs)	1368
% loss in lane capacity	2.1%
adj. lane capacity @ 100% g	1125
adj. lane capacity/hr of green	427.5
capacity loss in pcph	8.9
PCE	2.2
Average PCE's on IB (eastbound) approach	1.7

proportional to the total time loss attributable to all peak hour buses divided by the total amount of green time per hour available to Washington Street. The capacity loss inflicted is stated in terms of passenger cars per hour (pcph) and the PCE of a single bus is defined as pcph/#buses causing the capacity loss.

On this basis, outbound Route 57 buses that stop in the curb lane in the PM peak hour have a PCE of 1.3, while those that stop in the through lanes have a much higher PCE of 2.3. The weighted average PCE of an outbound bus is then 1.7. Inbound buses exhibit nearly identical PCE values.

These derived PCE's of Route 57 buses were then added to observed non-transit Washington Street vehicular through volumes and using the CINCH computer program, current performance measures of the intersection's operation were computed.[3] Table F-2 summarizes some of the results of this process. It shows that the V/C ratios on the four approaches range from .86 to .89. Also, the average stopped delay per vehicle (ASD/V) ranges from 19.04 to 24.72 seconds, giving associated LOS values of C in all cases. The ASD/V and LOS for the intersection as a whole are 21.58 seconds and C, respectively.

Table F-2
Intersection Performance With/Without Washington Street Buses

	V/C		ASD/V		LOS	
	with	without	with	without	with	without
Eastbound	.88	.86	24.72	22.74	C	C
Westbound	.86	.83	23.00	21.35	C	C
Southbound	.89	.89	19.78	19.78	C	C
Northbound	.86	.86	19.04	19.04	C	C
Total Intersection	.77	.76	21.58	20.70	C	C

In other words, the intersection currently works fairly well and in comparing its performance now with its performance assuming no buses on Washington Street shows that buses do not seriously degrade traffic. Without buses, the eastbound Washington Street approach would experience 1.98 fewer seconds of ASD/V and the westbound approach would experience 1.65 fewer seconds of ASD/V.

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[3] CINCH program written by Dan Beagan, CTPS, February 6, 1987. Based on procedures from the 1985 Highway Capacity Manual.

Conditions With Trolleys

To estimate the effect that trolleys would have on the study intersection, the same basic process described above was employed. Differences occurred in calculating the dwell times of trolleys, and the degree to which they would impact traffic in lanes other than the one they would occupy.

An individual trolley would have different dwell time characteristics than a bus and a greater traffic impact due to its having to stop in a through traffic lane 100 percent of the time (the inside lane in this case), and by the difficulty encountered by other vehicles in negotiating around a stopped trolley.

The input data required for the determination of average trolley dwell time included an estimate of the boardings and alightings at the two stops of interest and the assumed service times per passenger.

The number of boardings and alightings at Washington and Market/Chestnut Hill would vary by trolley design scenario and by whether Route 301 were retained. They were estimated for the five scenarios that specify trolley service as far west as Brighton Center by first factoring existing Route 57 boardings and alightings upwards. The factors were based on the relationship between estimated peak hour trolley boardings and alightings and current Route 57 peak hour boardings and alightings on the route segment that includes the study intersection. In all cases, total PM peak hour trolley boardings on this segment would be higher than current Route 57 boardings. Combined with longer trolley headways and higher trolley capacity, more passengers per vehicle would board and alight at the stops of interest.

In addition, for scenarios without Route 301, the estimated share of the 75 PM peak-hour travellers who now alight in Brighton Center who would be diverted to the trolley was added to the other alightings at the Washington at Waldo stop. These are travellers who now alight either at the far-side Washington opposite Waldo stop or at the last stop at Winship and Union.

Once estimates of trolley boardings and alightings for the two stops of interest were obtained, they were factored by service times. Based on field observations and national data, the following service times were assumed: outbound boarding, 2.0 seconds; outbound alighting, 1.1 second; inbound boarding, 2.2 seconds; and inbound alighting, 1.1 second.

Inbound service time per boarding exceeds outbound due to patrons having to pay inbound but not outbound. Neither is as low as it would be if all three doors could be used, but

for passenger safety, MBTA policy specifies front door operation only on mixed rights-of-way, which is what would exist in Brighton Center. (Fare collection dictates sole use of the front door, inbound, in any case.)

Values for dead time and loss time are the same as for buses: 5.0 and 6.0 seconds respectively. Signal and lane capacity characteristics are, of course, also the same.

Depending on the scenario, outbound dwell time per trolley ranges from 25.6 to 40.4 seconds. Inbound dwell time ranges from 16.9 to 20.5 seconds. These and other measures used in calculating trolley PCE's are shown in Table F-3. These dwell times are greater than those for buses because of the higher passenger service volumes per vehicle alluded to above.

The calculation of the PCE of a trolley in its lane of operation was the same as for a bus that stops in a through lane. The time loss inflicted on the vehicle stream is a function of the g/C ratio, the number of stopped trolleys (ranging from 88 percent of through trolleys if Route 301 is retained to 100 percent if Route 301 is eliminated), and the sum of the dwell and loss times.

In addition to capacity loss in its lane of operation, a trolley would impact the traffic stream in the outside through lane as well. It is illegal to pass a trolley on the right when its doors are open. At the study intersection, depending on parking and snow conditions and on the size of the passing vehicle, a vehicle could not always squeeze by on the right even for the moments when the stopped trolley's doors were closed (dead time).

Due to these considerations, the analysis assumed that half the time, a vehicle could pass the stopped trolley on the right, but only when its doors are closed. It was assumed that vehicles in this case would be impacted by the passenger service time component of dwell time and one-half the normal loss time. The other half of the time, vehicles in the outside lane would have no opportunity to pass on the right and would therefore be affected in the same manner as vehicles in the inside lane.

As shown in Tables F-3a through F-3e, the trolleys would have a PCE of from 7.0 to 10.5 in the outbound intersection approach and from 5.0 to 5.8 inbound. The greater outbound impact results, notwithstanding slightly lower average passenger service times, from higher passenger service volumes - mainly alightings - in this case. Compared to current bus service, then, trolleys would have a PCE equivalent three to six times greater.

Watertown Trolley Analysis, Table F-3a
Passenger Car Equivalents of Trolleys - PM Peak Hour
Washington @ Market/Chestnut Hill
Alternative: 2. Watertown - Park Street, Eliminate 301

INPUTS:	
PM peak period boardings	2373
PM peak period vehicle trips	12
Assumed percentage of trips that stop	100%
Service time/ boarding - OB (Sb)	2.0
Service time/ alighting - OB (Sa)	1.1
Service time/ boarding - IB (Sb)	2.2
Service time/ alighting - IB (Sa)	1.1
Dead time/ vehicle (d)	5.0
Lost time/ vehicle (L)	6.0
green/Cycle (g/C)	0.38
Lane capacity @100% green (c)	1125
Available green time/ hour	1368
Trolley boardings - OB	1.8
Trolley alightings - OB	23.5
Trolley boardings - IB	3.6
Trolley alightings - IB	3.6
INTERMEDIATE CALCULATIONS:	
Boardings on peak hour trips	1281
One-way stopped trolleys (n)	6
Dwell time/ Vehicle - OB (D)	34.5
Dwell time/ Vehicle - IB (D)	16.9
CALCULATION OF PCE's:	
OUTBOUND:	
Inside lane	
Time loss @ (g/C)*n*(D+L)	92.2
% loss in lane capacity	6.74%
Capacity loss in pass cars per hour (pcph)	28.8
Passenger car equivalents (PCE's)	**4.8**
Outside lane	
Time loss @ ((g/C)*.5n*(D+L)) + ((g/C)*.5n*(S+.5L)	83.1
% loss in lane capacity	6.08%
Capacity loss in pass cars per hour (pcph)	26.0
Passenger car equivalents (PCE's)	**4.3**
Total PCE's on OB (westbound) approach	**9.1**
INBOUND:	
Inside lane	
Time loss @ (g/C)*n*(D+L)	52.2
% loss in lane capacity	3.81%
Capacity loss in pass cars per hour (pcph)	16.3
Passenger car equivalents (PCE's)	**2.7**
Outside lane	
Time loss @ ((g/C)*.5n*(D+L)) + ((g/C)*.5n*(S+.5L)	43.0
% loss in lane capacity	3.15%
Capacity loss in pass cars per hour (pcph)	13.5
Passenger car equivalents (PCE's)	**2.2**
Total PCE's on IB (eastbound) approach	**5.0**

Watertown Trolley Analysis, Table F-3b
Passenger Car Equivalents of Trolleys - PM Peak Hour
Washington @ Market/Chestnut Hill
Alternative: 3. Newton Corner - Park Street, Eliminate 301

INPUTS:	
PM peak period boardings	2065
PM peak period vehicle trips	10
Assumed percentage of trips that stop	100%
Service time/ boarding - OB (Sb)	2.0
Service time/ alighting - OB (Sa)	1.1
Service time/ boarding - IB (Sb)	2.2
Service time/ alighting - IB (Sa)	1.1
Dead time/ vehicle (d)	5.0
Lost time/ vehicle (L)	6.0
green/Cycle (g/C)	0.38
Lane capacity @100% green (c)	1125
Available green time/ hour	1368
Trolley boardings - OB	2
Trolley alightings - OB	26.6
Trolley boardings - IB	4
Trolley alightings - IB	4
INTERMEDIATE CALCULATIONS:	
Boardings on peak hour trips	1115
One-way stopped trolleys (n)	5
Dwell time/ Vehicle - OB (D)	38.3
Dwell time/ Vehicle - IB (D)	18.2
CALCULATION OF PCE's:	
OUTBOUND:	
Inside lane	
Time loss @ (g/C)*n*(D+L)	84.1
% loss in lane capacity	6.15%
Capacity loss in pass cars per hour (pcph)	26.3
Passenger car equivalents (PCE's)	5.3
Outside lane	
Time loss @ ((g/C)*.5n*(D+L)) + ((g/C)*.5n*(S+.5L)	76.5
% loss in lane capacity	5.59%
Capacity loss in pass cars per hour (pcph)	23.9
Passenger car equivalents (PCE's)	4.8
Total PCE's on OB (westbound) approach	10.0
INBOUND:	
Inside lane	
Time loss @ (g/C)*n*(D+L)	46.0
% loss in lane capacity	3.36%
Capacity loss in pass cars per hour (pcph)	14.4
Passenger car equivalents (PCE's)	2.9
Outside lane	
Time loss @ ((g/C)*.5n*(D+L)) + ((g/C)*.5n*(S+.5L)	38.4
% loss in lane capacity	2.81%
Capacity loss in pass cars per hour (pcph)	12.0
Passenger car equivalents (PCE's)	2.4
Total PCE's on IB (eastbound) approach	5.3

Watertown Trolley Analysis, Table F-3c
Passenger Car Equivalents of Trolleys - PM Peak Hour
Washington @ Market/Chestnut Hill
Alternative: 4a. Oak Square - Park Street, Eliminate 301

INPUTS:	
PM peak period boardings	1644
PM peak period vehicle trips	9.2
Assumed percentage of trips that stop	100%
Service time/ boarding - OB (Sb)	2.0
Service time/ alighting - OB (Sa)	1.1
Service time/ boarding - IB (Sb)	2.2
Service time/ alighting - IB (Sa)	1.1
Dead time/ vehicle (d)	5.0
Lost time/ vehicle (L)	6.0
green/Cycle (g/C)	0.38
Lane capacity @100% green (c)	1125
Available green time/ hour	1368
Trolley boardings - OB	2.2
Trolley alightings - OB	28.2
Trolley boardings - IB	4.4
Trolley alightings - IB	4.4
INTERMEDIATE CALCULATIONS:	
Boardings on peak hour trips	888
One-way stopped trolleys (n)	4.6
Dwell time/ Vehicle - OB (D)	40.4
Dwell time/ Vehicle - IB (D)	19.5
CALCULATION OF PCE's:	
OUTBOUND:	
Inside lane	
Time loss @ (g/C)*n*(D+L)	81.1
% loss in lane capacity	5.93%
Capacity loss in pass cars per hour (pcph)	25.4
Passenger car equivalents (PCE's)	5.5
Outside lane	
Time loss @ ((g/C)*.5n*(D+L)) + ((g/C)*.5n*(S+.5L)	74.2
% loss in lane capacity	5.42%
Capacity loss in pass cars per hour (pcph)	23.2
Passenger car equivalents (PCE's)	**5.0**
Total PCE's on OB (westbound) approach	**10.5**
INBOUND:	
Inside lane	
Time loss @ (g/C)*n*(D+L)	44.6
% loss in lane capacity	3.26%
Capacity loss in pass cars per hour (pcph)	13.9
Passenger car equivalents (PCE's)	**3.0**
Outside lane	
Time loss @ ((g/C)*.5n*(D+L)) + ((g/C)*.5n*(S+.5L)	37.6
% loss in lane capacity	2.75%
Capacity loss in pass cars per hour (pcph)	11.8
Passenger car equivalents (PCE's)	**2.6**
Total PCE's on IB (eastbound) approach	**5.6**

Watartown Trolley Analysis, Tabla F-3d
Passangar Car Equivalants of Trolleys - PM Peak Hour
Washington @ Markat/Chestnut Hill
Alternative: 4b. Oak Square - Park Street, Retain Shortened 301

INPUTS:	
PM peak period boardings	1262
PM peak period vehicle trips	9.2
Assumed percentage of trips that stop	88%
Service time/ boarding - OB (Sb)	2.0
Service time/ alighting - OB (Sa)	1.1
Service time/ boarding - IB (Sb)	2.2
Service time/ alighting - IB (Sa)	1.1
Dead time/ vehicle (d)	5.0
Lost time/ vehicle (L)	6.0
green/Cycle (g/C)	0.38
Lane capacity @100% green (c)	1125
Available green time/ hour	1368
Trolley boardings - OB	2.2
Trolley alightings - OB	17.2
Trollay boardings - IB	4.4
Trolley alightings - IB	4.4
INTERMEDIATE CALCULATIONS:	
Boardings on peak hour trips	681
One-way stopped trolleys (n)	4.048
Dwell time/ Vehicle - OB (D)	28.3
Dwell time/ Vehicle - IB (D)	19.5
CALCULATION OF PCE's:	
OUTBOUND:	
Inside lane	
Time loss @ (g/C)*n*(D+L)	52.8
% loss in lane capacity	3.86%
Capacity loss in pass cars per hour (pcph)	16.5
Passenger car equivalents (PCE's)	4.1
Outside lane	
Time loss @ ((g/C)*.5n*(D+L)) + ((g/C)*.5n*(S+.5L)	46.6
% loss in lane capacity	3.41%
Capacity loss in pass cars per hour (pcph)	14.6
Passenger car equivalents (PCE's)	3.6
Total PCE's on OB (westbound) approach	7.7
INBOUND:	
Inside lane	
Time loss @ (g/C)*n*(D+L)	39.3
% loss in lane capacity	2.87%
Capacity loss in pass cars per hour (pcph)	12.3
Passenger car equivalents (PCE's)	3.0
Outside lane	
Time loss @ ((g/C)*.5n*(D+L)) + ((g/C)*.5n*(S+.5L)	33.1
% loss in lane capacity	2.42%
Capacity loss in pass cars per hour (pcph)	10.3
Passenger car equivalents (PCE's)	2.6
Total PCE's on IB (eastbound) approach	5.6

Watertown Trolley Analysis, Table F-3e
Passenger Car Equivalents of Trolleys - PM Peak Hour
Washington @ Market/Chestnut Hill
Alternative: 5. Brighton Center - Park Street, Retain 301

INPUTS:	
PM peak period boardings	730
PM peak period vehicle trips	8.6
Assumed percentage of trips that stop	88%
Service time/ boarding - OB (Sb)	2.0
Service time/ alighting - OB (Sa)	1.1
Service time/ boarding - IB (Sb)	2.2
Service time/ alighting - IB (Sa)	1.1
Dead time/ vehicle (d)	5.0
Lost time/ vehicle (L)	6.0
green/Cycle (g/C)	0.38
Lane capacity @100% green (c)	1125
Available green time/ hour	1368
Trolley boardings - OB	2.4
Trolley alightings - OB	14.4
Trolley boardings - IB	4.7
Trolley alightings - IB	4.7
INTERMEDIATE CALCULATIONS:	
Boardings on peak hour trips	394
One-way stopped trolleys (n)	3.784
Dwell time/ Vehicle - OB (D)	25.6
Dwell time/ Vehicle - IB (D)	20.5
CALCULATION OF PCE's:	
OUTBOUND:	
Inside lane	
Time loss @ (g/C)*n*(D+L)	45.5
% loss in lane capacity	3.33%
Capacity loss in pass cars per hour (pcph)	14.2
Passenger car equivalents (PCE's)	**3.8**
Outside lane	
Time loss @ ((g/C)*.5n*(D+L)) + ((g/C)*.5n*(S+.5L)	39.7
% loss in lane capacity	2.91%
Capacity loss in pass cars per hour (pcph)	12.4
Passenger car equivalents (PCE's)	**3.3**
Total PCE's on OB (westbound) approach	**7.0**
INBOUND:	
Inside lane	
Time loss @ (g/C)*n*(D+L)	38.1
% loss in lane capacity	2.79%
Capacity loss in pass cars per hour (pcph)	11.9
Passenger car equivalents (PCE's)	**3.1**
Outside lane	
Time loss @ ((g/C)*.5n*(D+L)) + ((g/C)*.5n*(S+.5L)	32.4
% loss in lane capacity	2.37%
Capacity loss in pass cars per hour (pcph)	10.1
Passenger car equivalents (PCE's)	**2.7**
Total PCE's on IB (eastbound) approach	**5.8**

Of primary interest, though, is the extent to which trolleys would affect intersection performance measures. Total trolley PCE's for the PM peak hour for each scenario were added to the observed Washington Street through volumes in the same manner as in the bus alternative. The results are shown in Table F-4 alongside those for the base case bus alternative.

Table F-4
Intersection Performance Measures

	ALTERNATIVES					
	Bus	Trolley				
	0	2	3	4a	4b	5
Eastbound:						
V/C	.88	.93	.92	.92	.91	.91
ASD/v	24.72	29.51	28.61	28.30	27.25	26.75
LOS	C	D	D	D	D	D
Westbound:						
V/C	.86	.92	.92	.91	.90	.89
ASD/v	23.00	28.45	27.47	27.11	25.51	24.90
LOS	C	D	D	D	D	C
Total Intersection:						
V/C	.77	.79	.79	.79	.78	.78
ASD/v	21.58	24.14	23.66	23.50	22.83	22.56
LOS	C	C	C	C	C	C

The most noticeable impact that trolleys would have would be to change the LOS on the two Washington Street approaches from C to D in almost all cases. Depending on the alternative, from 2 to 5 seconds of delay would be added to both directions during the peak hour. The V/C ratios would increase three to six points.

In real terms, going from a LOS of C to D would mean that motorists would go from a situation in which individual signal cycle failures only occasionally occur, to a situation in which individual cycle failures become more noticeable and the portion of vehicles compelled to stop increases.[4]

Total intersection delay, including all four approaches, would increase by 0.98 to 2.56 seconds of ASD/V, but the LOS would remain constant at C. The longer trolley alternatives with their higher numbers of vehicle trips would impart the most delay.

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[4] Cycle failure is defined as the inability of all waiting vehicles to clear the intersection on a single green phase.

To summarize, trolley operations would have a greater negative impact on the traffic stream than buses now do. Trolleys are less maneuverable than buses. They would operate directly in the traffic stream and would affect a wider section of the approach. Often, too, due to their serving higher passenger volumes per stop, due to longer headways and more capacity per vehicle, their total dwell time in the intersection in the peak hour would exceed that of buses, even though the latter would be more frequent and have higher average service times. This would be especially so if Route 301 were eliminated because outbound alighting would be shifted to a near side trolley stop - Washington at Waldo - from a far side express bus stop - Washington opposite Waldo. In addition, alightings would be shifted to this stop from 301's last stop at Winship and Union.

Other Locations

In addition to Washington at Market/Chestnut Hill, there are ten other signalized intersections along the trolley alignment in Allston/Brighton. Those in Union Square and at Washington and Cambridge Streets are more complex than the study intersection and traffic volumes differ by intersection. However, the order of magnitude of the difference between trolley and bus impacts at the study intersection could reasonably be expected to hold at other intersections.

Impacts at mid-block stops and non-signalized intersections would generally be less noticeable. Stopped trolleys in those places would not be compounding the capacity restrictions imposed by traffic signals, and since the signalized intersections largely control the capacity of the Route 57/trolley alignment, overall delay from trolleys stopping elsewhere would be smaller.

F.3.1.b Impacts of Trolley Priority Schemes

Three different trolley priority schemes were considered in the Watertown Trolley Analysis (See Appendix A for details): a subway under Brighton Center, reservations on Cambridge Street and Brighton Avenue, and signal pre-emption. The first would reduce transit's impact on traffic, the second would increase its impact, and the net impact of the third is unclear, but would probably be minor.

Subway tunnel

The subway tunnel would have at least one noticeable effect on traffic: it would eliminate transit vehicles from traffic on the Washington Street approaches of the Washington and Market/Chestnut Hill intersection. As a result, traffic conditions at that intersection would be improved at least to

the levels shown in Table F-2 (without buses). As specified, the roughly half-mile tunnel would also divert transit vehicles from two other signalized intersections: Washington and Cambridge/Winship as well as Washington and Foster. It is not known precisely to what degree conditions at these intersections would improve, but the change, at least at the former, would likely be noticed.

Furthermore, since the tunnel's contribution to increased line volumes on the A-line would be small (See Appendix A), any overall reduction in traffic as a result of increased mode shifting would probably be very small. No definitive statement can be made in this regard, though, since the demand analysis makes no attempt to estimate the number of automobiles that would be pulled off of the trolley/Route 57 alignment.

Reservations

Reserved rights-of-way for trolleys would have to be created on Cambridge Street and Brighton Avenue by taking capacity away from non-transit vehicles. In the former, the capacity loss would be quite severe in places and in the latter, the loss would be significant, but less severe.

On Cambridge Street between Warren and Gordon Streets, the effective road width is sufficient that a trolley reservation would leave one full-width vehicular lane per direction. In other words, a reservation could be physically accomodated on this stretch, equivalent to about half the distance between Union Square and Cambridge and Washington Streets, but at the cost of close to half the roadway's total capacity.

Closer to Union Square and Brighton Center, effective road width is narrower, due to a physically narrower road and on-street parking. A trolley reservation on these segments would, then, have a greater impact on roadway capacity under present conditions. Due to curb lane parking, only a narrow through lane would remain for non-transit vehicles. Banning parking was not assumed since the impact would probably be unacceptable to residents and businesses alike.

A reservation on Brighton Avenue would be easier to accommodate. In fact, one existed there until the late 1940's when it was eliminated in a city-wide effort to increase roadway capacity. However, a reservation there would probably serve little useful purpose other than passenger safety at stops. Currently, the roadway is wide enough, the tracks are offset toward the median enough, and volumes low enough that vehicular traffic generally does not encroach on the tracks. Therefore, a reservation would not significantly speed trolley service, especially when factored into the terminal-to-terminal line speed.

On the other hand, creation of a reservation would detract noticeably from the roadway capacity of this segment. When the A-line operated in the 1940's, traffic volumes were lower, demand for on-street parking was lower and parking enforcement was better. Rebuilding the reservation given prevailing traffic and parking conditions would result in a greater impact on traffic than was represented by its existence in the 1940's. Under prevailing conditions, close to one lane per direction would be taken from non-transit vehicles and given to transit vehicles.

Signal Preemption

Generally, transit vehicles should only be allowed to preempt signals at intersections where cross-street volumes are not too great. Otherwise, delays for cross-street travellers can become intolerable and the intersection could fail. Of the eleven signalized intersections in Allston/Brighton along the Route 57/trolley alignment, six are deemed candidates for preemption, based on field observations of cross-street volumes. The six are:

- Washington at Brock/Lake Streets
- Washington at Foster
- Cambridge at Warren/Sparhawk Streets
- Cambridge at Eleanor
- Cambridge at Gordon
- Brighton Avenue at Linden

The effect of signal pre-emption on traffic would be to "transfer" capacity from cross-streets to the main street, by shifting the amount of available green time around. To the extent that signals are currently optimally timed, pre-emption of the normal cycles could cause the overall workings of the intersection to degrade. Also, the higher the cross-street volumes are relative to main street volumes, the more significant would be the impact. However, in the absence of complete traffic, geometric and signal information on each intersection, the overall impact of pre-emption cannot be fully predicted in terms of commonly used intersection performance measures.

Various types of pre-emption exist and each can be set up to interact with the signals in various ways. For simplicity, if it is assumed that each trolley vehicle automatically pre-empted each signal to the extent that 10 seconds of available green time were shifted from the cross to the main street, then the conditions shown in Table F-5 would occur. Cross-streets would lose 120 seconds of green time per hour which would be equivalent to 11 to 15 percent of the green time that they now have available.

Table F-5
Effects of Signal Pre-emption In Allston/Brighton

Intersection	Major East-West Approaches				Cross-street Approaches				Cycle Length	Cross-Street green time/hour (secs.) Now and With 12 Trolleys/Hour*			
	Green	Yellow	Red	%Green	Green	Yellow	Red	%Green		Now	w/trolleys	Lost	%Lost
Brighton @ Linden	33	4	19	59%	15	4	37	27%	56	964	844	120	12%
Cambridge @ Gordon	26	4	15	58%	11	4	30	24%	45	880	760	120	14%
Cambridge @ Sparhawk	39	4	25	57%	21	4	43	31%	68	1112	992	120	11%
Washington @ Foster	40	4	18	65%	14	4	44	23%	62	813	693	120	15%
Washington @ Brock	34	4	19	60%	15	4	38	26%	57	947	827	120	13%
TOTAL										4716	4116	600	13%

* Assumes pre-emption of 10 seconds from cross-street per trolley. Trolleys are 2-way.
Source for signal information: CTPS field checks.

Given qualitative impressions from field checks that cross-street volumes are not high relative to main street volumes, and given the modest shifting of available green time, hence capacity, that would probably occur, cross-street traffic impacts from signal pre-emption would not be great.

F.3.2 Downtown Boston

Since approximately six months prior to the suspension of service on the A-Line, direct service to downtown Boston has been provided on Route 301. Were service on the A-line to be re-instituted, Route 301 could be eliminated. However, the elimination of Route 301 would have little, if any, impact on traffic in the downtown area. Along most of the route, traffic volumes are below capacity during the periods the route operates, to the extent that the presence of Route 301 buses does not cause delays. At intersections where delays do occur, the level of service on Route 301 is so low in relationship to total volumes that the elimination of the route would not result in a noticeable improvement in traffic conditions.

F.3.2.a Route 301 Alignment

At present, Route 301 provides express service between Brighton Center and downtown Boston via Oak Square and Newton Corner. Service operates from 6:35 to 9:38 AM in the AM peak period, and from 1:48 PM to 7:25 PM in the afternoon and evening. During the AM peak, service operates on headways of five minutes or less; during the PM peak, service operates on headways of three to ten minutes.

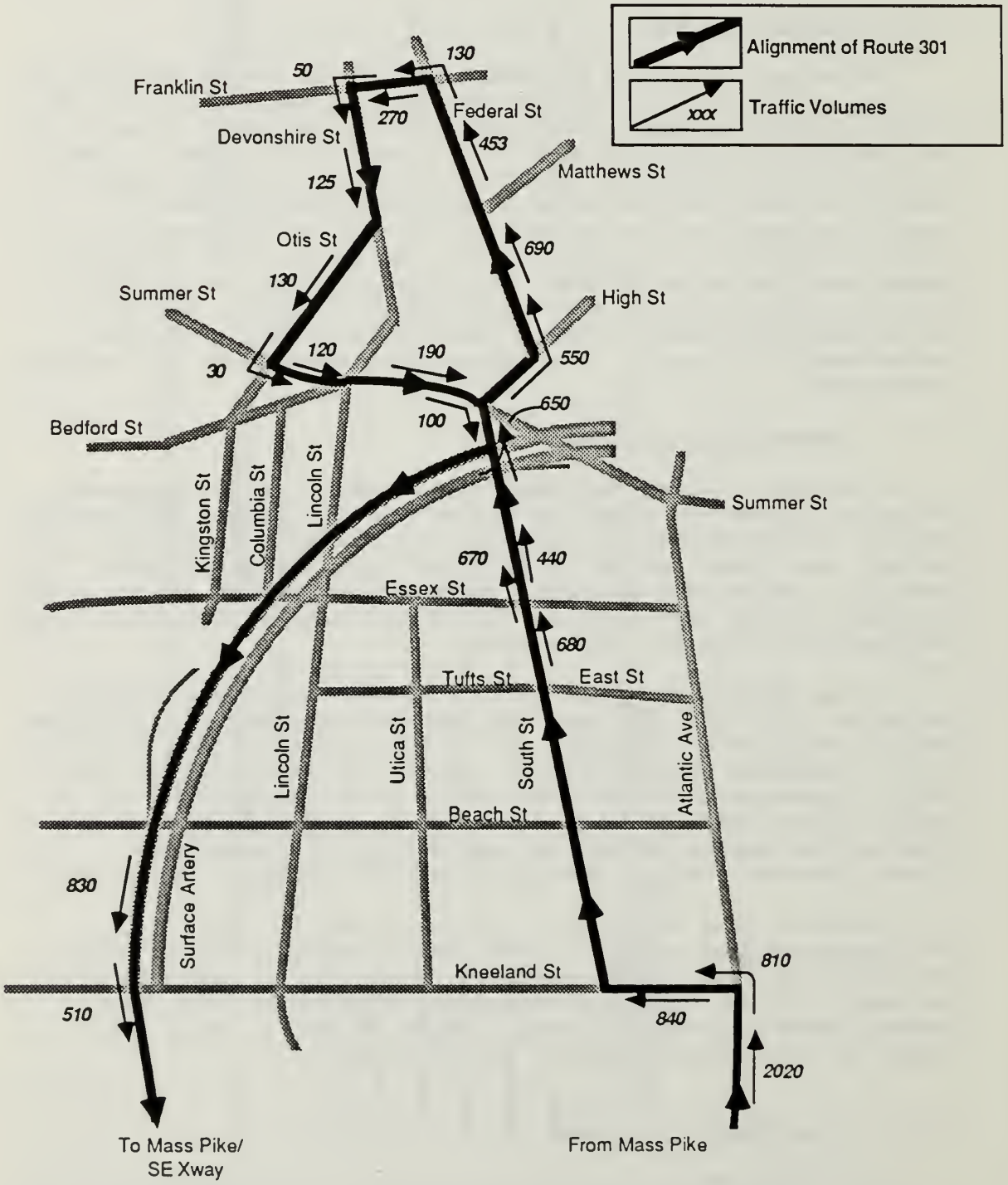
At the Boston end, the route follows the same alignment as Routes 300, 304, 305 and 310 between the Mass Pike and the end of the line at Federal and Franklin Streets (see Figure F-1). Inbound, this alignment leaves the Mass Pike at the South Station exit, then goes left on Kneeland, right on South, right on High, and left on Federal to the end of the line at the corner of Federal and Franklin Streets. All streets in the inbound direction are two or three lanes wide.

Outbound, the route goes left on Franklin, left on Devonshire, right at Otis, left onto Summer, right on South and right onto the Surface Artery, straight to the Mass Pike on-ramp. In the outbound direction, Devonshire and Otis Streets have two narrow lanes, Summer Street is only one lane, and the Surface Artery is three lanes.

F.3.2.b Bus/Traffic Volumes

Currently, Route 301 is one of five bus routes that share the same alignment between the Mass Pike and Federal and

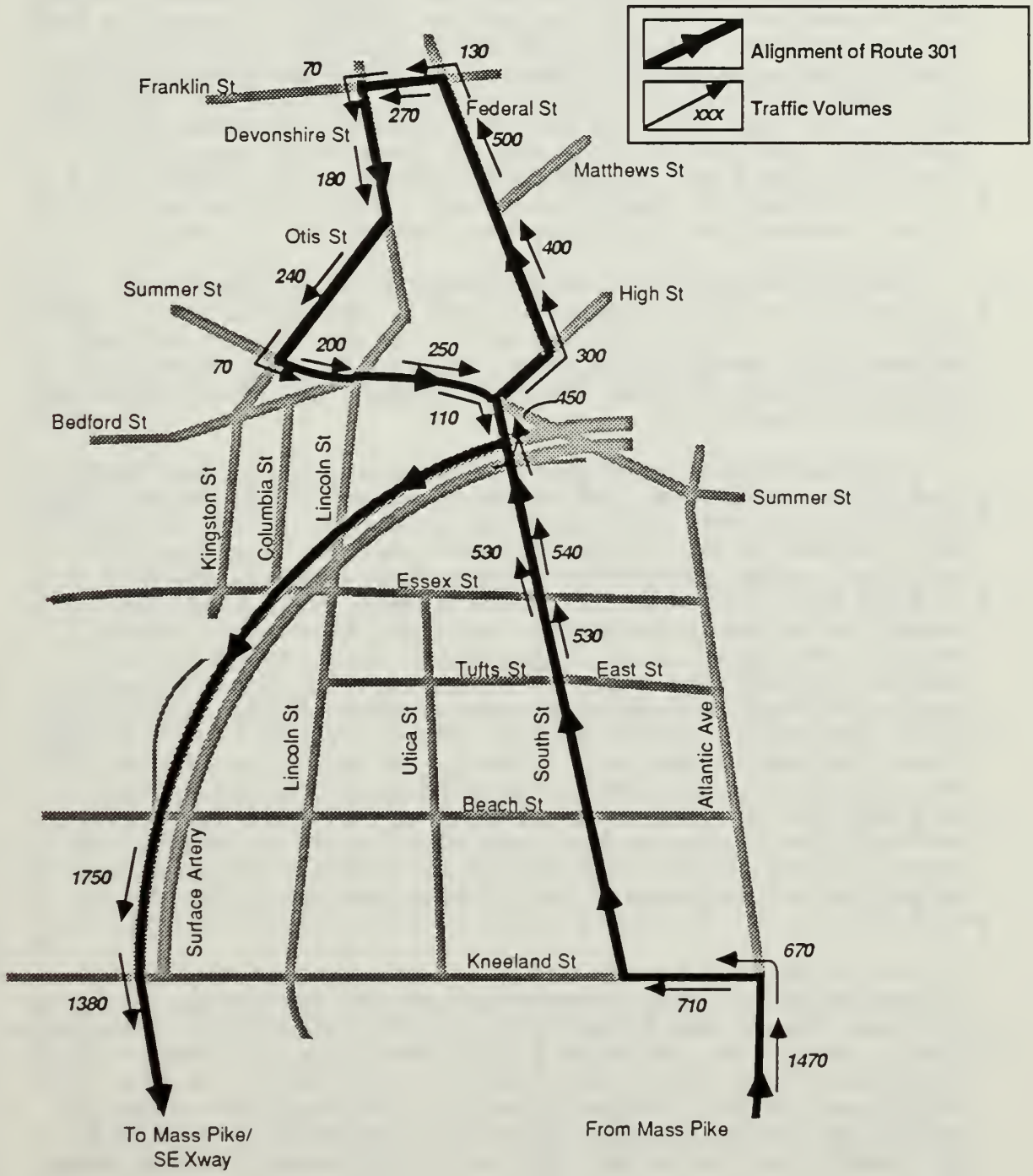
Figure F-1
Traffic Volumes Along the Downtown Boston Segment of Route 301 (8:00-9:00 AM)



Note: Traffic volumes from various sources, 1978 - 1984, expanded to represent 1984 volumes.

Figure F-2

Traffic Volumes Along the Downtown Boston Segment of Route 301 (4:00-5:00PM)



Note: Traffic volumes from various sources, 1978 - 1984, expanded to represent 1984 traffic volumes.

Franklin Streets. During the AM peak period, 107 bus trips travel along all or part of the alignment, 24 percent (26) of which are Route 301 trips (see Table F-6). During the PM peak period, 90 bus trips are present, with 21 percent (19) of these being Route 301 trips. In total, during the PM peak period, when bus volumes are heaviest, bus traffic from all trips on these five routes accounts for approximately three to 26 percent of total intersection approach volumes. (Where percentages are high, it is because traffic volumes are low; low percentages indicate high total volumes and potential traffic delay problems.) Route 301 buses account for from less than one percent to four percent. During the AM peak period, between 8:00 and 9:00 AM, when bus volumes are heaviest, bus traffic from all of these five routes (68 trips) accounts for approximately three to 54 percent of total intersection approach volumes. Route 301 buses (16 trips) account for less than one percent to 13 percent.

Traffic counts have been conducted at a number of intersections along the Boston end of the route over the last eight years. The volumes observed in the AM peak period between 8:00 and 9:00 AM from 1981 to 1986 are shown in Figure F-1, and PM peak volumes between 4:00 and 5:00 PM are shown in Figure F-2.

In the AM peak period, of the intersections for which counts are available, the highest volumes occur on the off-ramp from the Mass Pike to Kneeland Street (2020 vehicles), with volumes at all other intersections at less than 900 vehicles. When observed during this study, all traffic cleared all intersections in one signal cycle with the exception of the intersection of High Street and Federal Street. Delays at this intersection were caused by cars backing up from the entrance to the City of Boston parking garage located on Federal Street. (These delays continued until the garage filled shortly after 8:20 AM.) Along High Street between Summer and Federal, an exclusive lane exists for bus traffic, and delays experienced by buses at this intersection occured in the bus lane. Without Route 301 service, the exclusive bus lane would still be needed for the other express routes terminating at Federal and Franklin, so an additional lane would not be made available for other traffic.

In the PM peak period between 4:00 and 5:00 PM, high volumes occur at the intersection of the Mass Pike off ramp, Kneeland Street and Atlantic Ave.(1470 vehicles from the Mass Pike), and at the entrance to the Mass Pike and Southeast Expressway from the Surface Artery and Kneeland Street (1750 southbound on the Surface Artery). However, when observed, vehicular traffic on the Route 301 alignment cleared all intersections, including the two listed above, in one cycle.

Watertown Trolley, Table F-6
Number of Buses Arriving @ Federal and Franklin, per Hour
(Includes buses arriving to begin first run from Federal & Franklin.)

	6:00 AM to 6:59 AM	7:00 AM to 7:59 AM	8:00 AM to 8:59 AM	9:00 AM to 9:59 AM	1:00 PM to 1:59 PM	2:00 PM to 2:59 PM	3:00 PM to 3:59 PM	4:00 PM to 4:59 PM	5:00 PM to 5:59 PM	6:00 PM to 6:59 PM	7:00 PM to 7:59 PM
Route 300											
300	0	6	11	5	0	2	3	7	10	4	1
	0.0%	15.4%	16.2%	15.2%	0.0%	14.3%	13.0%	16.3%	21.3%	23.5%	11.1%
Route 301											
301.0	1	10	16	7	0	0	0	3	2	0	0
	12.5%	25.6%	23.5%	21.2%	0.0%	0.0%	0.0%	7.0%	4.3%	0.0%	0.0%
301.1	0	0	0	0	1	1	3	8	6	1	1
	0.0%	0.0%	0.0%	0.0%	14.3%	7.1%	13.0%	18.6%	12.8%	5.9%	11.1%
301 Total	1	10	18	7	1	1	3	11	8	1	1
	12.5%	25.6%	23.5%	21.2%	14.3%	7.1%	13.0%	25.6%	17.0%	5.9%	11.1%
Route 304											
304.0	3	8	15	5	2	2	6	8	9	5	1
	37.5%	20.5%	22.1%	15.2%	28.8%	14.3%	28.1%	14.0%	19.1%	29.4%	11.1%
304.1	2	1	9	5	2	5	3	7	6	3	2
	25.0%	2.6%	13.2%	15.2%	28.6%	35.7%	13.0%	18.3%	12.8%	17.6%	22.2%
304 Total	5	9	24	10	4	7	9	13	15	8	3
	62.5%	23.1%	35.3%	30.3%	57.1%	50.0%	39.1%	30.2%	31.9%	47.1%	33.3%
Route 305											
305	2	8	8	7	0	2	3	7	6	3	2
	25.0%	15.4%	8.8%	21.2%	0.0%	14.3%	13.0%	18.3%	12.8%	17.8%	22.2%
Route 310											
310.0	0	0	1	2	1	2	2	1	2	0	1
	0.0%	0.0%	1.5%	8.1%	14.3%	14.3%	8.7%	2.3%	4.3%	0.0%	11.1%
310.2	0	0	0	0	0	0	1	0	0	0	0
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.3%	0.0%	0.0%	0.0%	0.0%
310.3	0	4	5	0	0	0	1	3	5	1	1
	0.0%	10.3%	7.4%	0.0%	0.0%	0.0%	4.3%	7.0%	10.6%	5.9%	11.1%
310.5	0	2	1	2	1	0	1	0	0	0	0
	0.0%	5.1%	1.5%	8.1%	14.3%	0.0%	4.3%	0.0%	0.0%	0.0%	0.0%
310.6	0	2	4	0	0	0	0	1	1	0	0
	0.0%	5.1%	5.9%	0.0%	0.0%	0.0%	0.0%	2.3%	2.1%	0.0%	0.0%
310 Total	0	8	11	4	2	2	5	5	8	1	2
	0.0%	20.5%	18.2%	12.1%	28.6%	14.3%	21.7%	11.6%	17.0%	5.9%	22.2%
TOTAL - ALL ROUTES	*8*	*39*	*68*	*33*	*7*	*14*	*23*	*43*	*47*	*17*	*9*
	100%	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*

In summary, at present levels, traffic flows fairly smoothly along the alignment of Route 301 during both the AM and PM peaks with the exception of the intersection of High and Federal Streets. Due to the existence of an exclusive bus lane at that location, Route 301 buses do not worsen the existing traffic situation.

F.3.3 Newton Corner

Several issues become apparent in contemplating trolley operation through Newton Corner. These issues were examined primarily in a qualitative fashion due to the complexity of the roadway system there: detailed analysis such as that done in Brighton Center would have required far more time than was available. For present purposes, this is reasonable because most of the issues are most easily framed in qualitative terms. There is no definitive finding from the analysis as to how trolleys would affect Newton Corner traffic.

An essential consideration in operating trolleys through the area is the track alignment. As it exists now, trolleys operating southbound across the easternmost Centre/Washington Street bridge would operate counter to vehicular traffic as they did in the 1960's. If this routing were to be retained, then one of two actions would have to be taken. First, traffic signals designed to clear the entire bridge of vehicular traffic prior to a southbound trolley's passing could be provided. However, the stopped time that would thus be added to eastbound and westbound traffic, both north and south of the bridge, could have a significant impact. Perhaps most important, traffic exiting the Mass Pike westbound onto Centre Street would likely queue farther out onto the Pike than it now does during the PM peak period. This condition is already deemed to be a severe safety hazard, and any changes in the rotary that exacerbated it would likely be rejected.

A second option associated with operating trolleys southbound over the bridge would be to stripe/curb the road in such a way as to keep vehicular traffic out of the extreme western lanes where the tracks are. Aside from taking one-and-a-half lanes away from the five existing lanes, this would also create traffic/trolley conflicts in two locations. About two-thirds of the traffic on the bridge turns west onto either Washington Street or the turnpike on-ramp after leaving the bridge. Southbound trolleys on Centre Street would conflict with this traffic. In addition, southbound trolleys leaving the bridge would conflict with eastbound and northbound Centre/Washington Street traffic.

All things considered, and despite that trolleys used to be routed south across the bridge against traffic, it was assumed, on the basis of the considerations cited, that doing so now would be impractical. Although traffic volume counts

from the 1960's were unavailable for this analysis, it is reasonable to assume that volumes are higher now than they were when the A-line was in revenue operation and that, therefore, a southbound bridge routing would have a greater negative impact on traffic than it did before.

Alternatives to the present alignment include submerging it in a tunnel or elevating it over the roadway system. For purposes of the analysis contained in this and other appendices, neither of these options was assumed. They were deemed too costly and too likely to cause major problems during construction. A subway tunnel would have to be quite deep at this point as it would have to pass under the already below-grade Mass Pike and railroad alignment.

Instead, it was assumed that the tracks would be routed around the rotary over the westernmost Centre/Washington Street bridge so that trolleys, whether north or southbound, would always be operating in the same direction as vehicular traffic.

This alternative would have its problems. First, more street-running trackage would be introduced along Washington and Centre Streets. Many motorists view the tracks that already exist as a traffic hazard, so this addition would only intensify the perceived problem. Also, in the short-term, construction of the additional trackage would create major traffic problems in the rotary area.

Passenger safety would be an issue. Tracks would have to be routed so that passengers could board and alight trolleys safely at the curb. This would present a problem, though, to the extent that trolleys were routed in the vicinity of bus stops. It would be desireable to locate trolley stops away from bus stops so that the two modes did not interfere with each others operation and therefore compound general traffic delay in the area. It is not clear, however, that sufficient space exists to stop buses and trolleys apart.

The major issue is the degree to which trolley vehicles would impact traffic flow in the rotary. Using the difference between bus and trolley passenger-car-equivalents (PCE's) that were calculated for Brighton Center, and adding this difference to existing PM peak traffic volumes showed that the percentage increase in equivalent passenger car volumes in Newton Corner would be less than one percent. Again, though, since the rotary was not modelled, the real impacts on vehicular traffic are unclear.

It can be said with some certainty that since traffic volumes in the rotary are quite high and ever-increasing due to development in the area, trolleys would have an impact greater than that of the buses they would replace. The fixed guideway characteristic of a trolley would guarantee this: as

elsewhere, buses are more maneuverable than trolleys and are thus potentially less of an impediment to traffic flow. Furthermore, since more passengers would use the trolley than now use Routes 57 and 301, the trolleys would dwell in Newton Corner longer than the buses do.

Balancing the high volumes in the rotary is the fact that the roadway itself is quite wide. Trolleys operating along one side of it would not represent the same general degree of constriction of vehicular traffic that they would in Brighton Center. Bottlenecks, not now associated with buses, could occur though. For instance, the greater length of trolleys over buses could present a problem if northbound trolleys across the eastern bridge were stopped in the Center/Park Street intersection due to upstream delays.

Partially off-setting the potential traffic problems that would be posed by trolleys would be the possible beneficial effects associated with having a trolley line tied into a transportation center. The city of Newton has, for quite some time, been interested in the possibility of creating a transportation center in Newton Corner that would integrate various modes. A trolley line would be able to tie into such a system well. In fact, it would then become sensible to terminate the line at Newton Corner rather than Watertown Square because a transportation center would provide a natural turn-around facility.

APPENDIX G WATERTOWN TROLLEY HISTORY

G.1 INTRODUCTION

The purpose of this Appendix is to summarize the history of the Watertown Trolley, or A-line. Much of the history of this line was determined by general trends and events rather than by issues specific to its service corridor. Therefore, an attempt has been made to portray the broader context in which the A-line operated. The information in this appendix was taken from numerous sources, and whenever possible, facts were taken from sources contemporary with the events discussed.

G.2 EARLY TRANSIT HISTORY IN A-LINE CORRIDOR

The MBTA's transit network has developed over the course of more than 150 years. Most individual routes are the result not of one-time plans, but of many changes in routing, termini schedules and choice of vehicles to meet both changing travel requirements of the public, and fiscal constraints. Service in the Watertown trolley corridor is typical of this evolutionary process.

The neighborhoods formerly served by the A branch of the Green Line were among the first in greater Boston to be provided with public transportation. Brighton and Newton Corner were both stops on Boston's first steam railroad line, which opened in 1834. The Brighton stop was about three quarters of a mile from Brighton Center, and Watertown Square was less than half a mile from the Newton Corner stop. A station at Allston, near Union Square was added about 1853. By 1840, both Brighton and Watertown also had regularly-scheduled horse-drawn omnibus service to downtown Boston. The Watertown route was apparently short-lived, but the Brighton route was successful. In 1847, Watertown got its own steam railroad branch.

G.3 HORSECAR SERVICE

The first horse-drawn street railway line in the state opened in 1856, from Bowdoin Square in Boston via the West Boston Bridge to Harvard Square, and on to the Watertown-Cambridge border. The following year, it was extended to Watertown Square. Horsecar service directly in the A-line corridor began in 1858, when a branch line opened from Central Square in Cambridge through Union Square in Allston and Brighton Center to Oak Square. West of Union Square it followed the later route of the A-line. This branch was to have continued to Newton Corner, but probably due to financial problems, it was never finished. For the next 31 years, through horsecar service was provided from Bowdoin Square to Oak Square. The only other A-line segment served by horsecars was that from Newton Corner to Watertown,

which was covered by an extension of the Harvard Square-Watertown route in 1881.

G.4 ELECTRIC STREET RAILWAY CONSTRUCTION AND EARLY OPERATION

Boston's first significant electric street railway lines opened in 1889. The first route ran from Park Square via Boylston Street, West Chester Park (Massachusetts Avenue), and Beacon Street to Coolidge Corner in Brookline, followed Harvard Street and Harvard Avenue to Union Square, and then took the former horsecar route to Oak Square. The remainder of the present C-line between Coolidge Corner and Cleveland Circle opened at the same time.

The 1890s saw rapid expansion of trolley lines, both in the form of new routes, and as conversions of horsecar lines. Electrification of the Newton Corner-Watertown-Harvard-Bowdoin Square route was completed in 1893-94. In 1896, the Oak Square route was extended west to Park and Washington Streets in Newton Corner, on the south side of the Boston & Albany Railroad. At the same time, a new, more direct route from Union Square to what is now Kenmore Square was opened via Brighton Avenue and Commonwealth Avenue. This link was built in a center-of-street reservation provided by the City of Boston as part of a boulevard system then being constructed. In 1898, the final link across the railroad at Newton Corner was built, but extension of revenue service through to Watertown via Oak Square did not occur until many years later.

G.5 TREMONT AND BOYLSTON STREET SUBWAYS

The original service strategy pursued by the West End Street Railway Company, which built most of the early trolley lines in Boston and adjoining cities and towns, was to provide through service to downtown Boston from almost every route. This very shortly resulted in extreme congestion on major downtown streets. To reduce this surface streetcar traffic, America's first subway line was constructed by the Boston Transit Commission. The first segment, opened in 1897, included the Boylston and Park Street stations. Trolley lines that approached downtown on Boylston Street entered the subway at a portal near the Boston Public Garden. Most of these routes terminated at Park Street even after further extension of the subway to North Station in 1898. Service to North Station was provided by cars that entered through another portal at Tremont Street and Broadway, and ran through the two original stations on separate tracks.

In the early years of the Tremont Street subway, an attempt was made to run as many of the downtown trolley routes as possible into it. From the outset, this included the Brighton/Newton Corner route and the Cleveland Circle/Beacon Street route. The Commonwealth Avenue trolley route west of Packard's Corner, now the B-line, was added in 1900. So many other routes also used the subway that by 1906 in peak hours the average time be-

tween arrivals at Park Street was only about 15 seconds. Already, however, a new service pattern had begun to form which would help relieve this congestion.

Boston's first high-platform rapid transit line, predecessor to the Orange Line, opened in 1900. With it began the philosophy that passengers would be willing to trade a one-vehicle ride into downtown Boston for a much faster rapid transit trip on the last few miles. Thus, established trolley routes began to be cut back to outlying rapid transit stations, and removed from the Tremont Street Subway. The opening of the Cambridge Subway from Harvard to Park Street in 1912 similarly resulted in shortening of several lines from Cambridge and beyond that had formerly run into the Tremont Street Subway via the Harvard Bridge and Boylston Street.

The Boylston Street Subway opened in 1914, from the Public Garden portal to a portal just east of Kenmore Square. This new subway was used exclusively by the Brighton/Newton Corner, Commonwealth Avenue, and Beacon Street trolley lines. Several other routes continued to enter the subway at the Public Garden.

G.6 STREETCAR CUTBACKS AND BUS CONVERSIONS

The Massachusetts street railway industry was hard-hit by inflation caused by World War I and by growing popularity of automobiles. At the same time, much of the original rolling stock and track was in need of replacement. This resulted in the abandonment of most of the independent streetcar routes in Greater Boston between 1918 and 1930. The Boston Elevated Railway, or "El" which operated both the rapid transit system and the former West End Street Railway trolley network, was better able to survive than the smaller systems. This was both because it had greater traffic density and because the state legislature created a permanent subsidy mechanism for the El in 1918. Nevertheless, the El management was quick to investigate ways of eliminating its most unprofitable trolley lines. The first conversion of a Boston El trolley route to bus service took place in 1922. Ensuing years saw an ever-increasing number of conversions. The earliest bus substitutions were on routes that did not enter the subway.

G.7 REDUCTION OF SURFACE-SUBWAY ROUTINGS

In 1922 the El also began a new operating strategy for the trolley subway, to try to improve traffic flow. This consisted of running high-capacity multiple-car trains on the most heavily used routes, with some new short-turnback points near the subway terminals. Other, more lightly used trolley lines were no longer routed into the subway. Instead, they were terminated on the surface at trolley subway or rapid transit stations, or at outlying junctions with surviving surface-subway routes. The three routes using the Kenmore portal were all retained. The Newton Corner route was permanently extended through to Watertown

in 1922. Watertown had previously lost through trolley service to Boston as a result of the Cambridge Subway routing changes. In 1926, the first bus conversion of one of the truncated former surface-subway trolley routes took place. Direct conversions of surface-subway trolley routes to feeder bus routes were underway by the early 1930s.

In 1932, to relieve traffic problems at Kenmore Square, the subway was extended west from its old portal to new portals at Blandford Street on Commonwealth Avenue, and at St. Mary's Street on Beacon Street. A new underground station at Kenmore had four tracks: two for the Beacon Street line and two for the Commonwealth Avenue and Watertown lines. At this time, long-range plans called for conversion of the trolley subway to high-platform rapid transit service. The Beacon Street line was to end at a loop provided in the new Kenmore station. The Commonwealth Avenue subway was to be extended as a rapid transit line to some point along Commonwealth Avenue, possibly at Warren Street or beyond, where a transfer station for the other two trolley lines would be built. This plan was never carried out, but the start of the tunnel west of Kenmore was in place until 1986.

G.8 MTA OPERATION

As in other North American cities, conversion of the Boston trolley system to buses continued over many years. In 1947, the El was succeeded by the Metropolitan Transit Authority. As of 1958, all Boston trolley lines had been eliminated except five that entered the subway, and the Mattapan High Speed Line, which ran entirely on private right of way. The only development counter to this trend was the opening in 1959 of the Riverside extension over an abandoned commuter rail route. This line was tied into the Beacon Street route west of Kenmore. It was the first common-carrier trolley line built anywhere in the United States in several decades, and is often cited as the start of the Light Rail revival.

In 1961, the MTA announced plans to replace the Watertown Trolley line with buses to Kenmore Station. Strong opposition from public officials in Newton and Watertown prevented this from being done. At that time, the Watertown trolley line provided the only through transit service to downtown Boston from most points on its route. The Newton Corner commuter rail stop had been discontinued in 1959. Newton Corner and Watertown Square were important generators of Boston transit trips, both from local origins and from connecting bus routes.

G.9 MBTA OPERATION

In 1964, when the MTA was succeeded by the Massachusetts Bay Transportation Authority, the only routes still running in the trolley subway were the four Kenmore routes discussed above, plus the Arborway/Huntington Avenue line, which joined the others

near Copley Station. The A, B, C, D and E line designations for the five routes were applied in 1965, at the same time that the rapid transit lines began to be identified by color codes. The trolley subway became the Green Line.

The MTA had been the last buyer of new streetcars in North America with a 1951 order. The rest of the Green Line fleet was up to ten years older, and the MBTA recognized that replacement would soon be needed. Ordering new cars was delayed by the lack of a ready builder and a car design. Strategies other than a new car order were also under consideration, such as partial rapid transit conversion and partial bus replacement for the Green Line. In 1967, the MBTA proposed a trial replacement of the A Line with buses. This was deferred until express bus service to Boston from Watertown and Newton Corner was tested. The express service was successful and became permanent. In 1968, additional express bus routes were started from Watertown to Copley Square and from Brighton Center to downtown Boston.

G.10 BUS CONVERSION OF THE A-LINE

In 1969, faced with both a critical shortage of serviceable Green Line cars, and a mounting operating deficit, MBTA management once again proposed bus conversion of the Watertown or A-line. Of the five subway routes this was then the most logical candidate for conversion. It had the least ridership and made relatively inefficient use of vehicles because of slow speeds on unprotected street trackage. The Brighton Avenue reservation had been eliminated after World War II in a city project to increase traffic capacity. The line also had a record of poor reliability and frequent accidents. This was the first such conversion actually carried out since 1961. Unlike many earlier conversions, it faced strong opposition due largely to lobbying efforts of trolley advocates. The MBTA, therefore, announced that the conversion would initially be an 11-week experiment, to become permanent if successful. Bus service between Watertown and Kenmore station began on June 21, 1969. Because of criticism that a summer test would be unrepresentative, the MBTA agreed to extend the evaluation period to a full year.

Preliminary findings released by the MBTA in the Spring of 1970 showed that bus service had reduced the operating cost for the A Line by $325,000 a year, had reduced collision accidents more than 75%, and had reduced the number of delays by 90%. Furthermore, most riders were found to be in favor of retaining the bus service. On the basis of these findings, the A-line bus conversion was made permanent.

G.11 THE LIGHT RAIL REVIVAL

Historically, most trolley lines converted to bus service were dismantled shortly thereafter. At the time of the A-line conversion, however, the Watertown carhouse was still needed for heavy maintenance of Green Line vehicles. This function was

shifted to new facilities built at other locations in the mid-1970s, but Watertown continued to be used as the maintenance location for work cars. Therefore, the route remained intact, lending support to efforts to reinstate trolley service. This effort gained credibility as the result of revived interest in trolley service (renamed light rail to give it a more modern image) in many North American cities beginning about 1970.

Several new light rail lines have actually been built, more are under construction, and others are on the drawing boards. This does not, however, mean that all of the past decisions to replace trolleys with buses were inappropriate. A case-by-case examination of new light rail lines shows that most of them have been highly controversial. Including both operating costs and annualized capital costs, there are relatively few applications for which light rail would be less expensive than buses. In several cases, light rail service was chosen as a compromise when full rapid transit service was found to be prohibitively expensive. In general, new light rail lines make use of private rights of way, subways, or reservations. Street running is used only as a last resort, and then usually on streets where traffic can be restricted to transit vehicles. The fact that light rail service has been chosen for applications in other cities does not answer the question as to whether light rail is best for the A-line corridor. That must be determined by considerations pertaining to the A-line corridor itself.